



Transportation Synthesis Report

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Highway Clear Zones

Prepared for
Bureau of Highway Operations
Division of Transportation Infrastructure Development

Prepared by
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WisDOT RD&T Program
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Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research. Internet hyperlinks in TSRs are active at the time of publication, but changes on the host server can make them obsolete.

Request for Report

“Clear zone” refers to the desirable, unobstructed area along a roadway outside the edge of a traveled way that is available for the safe recovery of vehicles that have left the road.¹ The AASHTO Roadside Design Guide provides clear zone design and maintenance guidelines for states to use in establishing the zones.

Virtually everyone agrees that a flat, smooth, unobstructed area adjacent to the driving lanes is highly desirable and significantly improves roadside safety. There is some disagreement, however, on the matter of how wide to make this area.² The issues include the cost of clearing roadsides, which can greatly exceed the associated benefits to the traveling public,³ and the matter of tree removal, which can decrease the aesthetic value of roadways for motorists.

The RD&T Section was asked to gather specific information concerning the clear zone design and maintenance practices of other Midwest states, and to locate formal studies that quantify a safe distance between the traveled way and trees or other fixed objects.

¹Ohio DOT Location and Design Manual, Vol. 1 – Roadway Design; 600.2 [Pg. 4]- Clear Zone:
http://www.dot.state.oh.us/roadwayengineering/Publications/LDM1/LDM%20Set%20oct-29-04/600_oct04.pdf.

²Michigan DOT Road Design Manual, Ch. 7 – Appurtenances; 7.01.11 [Pg. 12]- Current Clear Zone Criteria:
<http://www.mdot.state.mi.us/design/englishroadmanual/>.

³Ibid., Ohio DOT Location and Design Manual- Clear Zone:
http://www.dot.state.oh.us/roadwayengineering/Publications/LDM1/LDM%20Set%20oct-29-04/600_oct04.pdf.

Summary

To locate information regarding states’ definition of clear zone, and their policies regarding the width of the zone, we reviewed the online design manuals for the states of Illinois, Iowa, Michigan, Minnesota, Missouri and Ohio. Pertinent excerpts from these manuals are presented below (**State Practices**). We wanted to zero in on several clear zone design and maintenance issues, and contacted staff members at the DOTs who could field the following questions:

- **Definition.** Does your DOT’s definition of clear zone apply to both the initial construction of the highway and also to vegetation management afterwards? (A copy of, or link to, the pertinent sections of your maintenance manual would be very helpful.)
- **Run-out zones.** Do you designate a particular distance beyond the bottom of a fill slope or a certain distance up a backslope that must be kept clear (free of trees)?
- **Traversable.** The WisDOT Facilities Development Manual and the AASHTO design guide both declare 4:1 slopes to be “traversable.” What are your criteria? (This has a bearing on the “run-out ” zone at the bottom of fill slopes.)

- Clear zones on roads with slopes. Does your definition of clear zone (the required width) vary depending on whether the road has a fill slope or cut slope?

Five of the six states provided answers to these questions (**State Practices**).

We located several formal studies that consider the issue of safe distance between fixed objects and the traveled way (**Research**):

- *A Guide for Addressing Collisions with Trees in Hazardous Locations*. This guide focuses on measures to reduce the harm in tree crashes after encroachment on the roadside has occurred, such as removing trees and shielding motorists from trees.
- *Investigation of Median Trees and Collisions on Urban and Suburban Conventional Highways in California*. The Caltrans Traffic Operations Program invited Cal Poly to perform a study of the safety of trees planted with limited side clearance in medians of urban and suburban conventional highways.
- *Trees and Roadside Safety in U.S. Urban Settings*. This study analyzes national traffic accident data to address questions relating to roadside attributes that are associated with accident incidence and severity, urban and rural spatial differences in accidents, the association between trees and roadside accident severity, and the implications for roadside planning, design and management.
- *Fatal Single Vehicle Crashes Study: Summary Report*. The cases in the study were fatal single-vehicle crashes (or crash trips) which occurred from Dec. 1, 1995 to Nov. 30, 1996 within 200 kilometers of Melbourne, AU. The major factors contributing to the severity of fatal single vehicle crashes were: trees and poles, not wearing seat belts and pre-1978 vehicles.

State Practices

Illinois

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- Definition. "So far as I know, our clear zone definition applies to both construction and maintenance of our highways."
- Run-out zones. "Trees of greater than 4 inches diameter are considered roadside hazards, similar to other objects such as culvert headwalls or concrete footings. Clear zones are established ideally to be areas free of such hazards. Yet, these areas are not sacrosanct. We strive to place or allow roadside hazards (if any) as far away from the roadway as possible, and certainly outside of the facility's established clear zone. However, due to limitations on additional right-of-way, prohibitive construction costs, or other factors, hazards are sometimes allowed to remain (in) the stated clear zone – and are sometimes not even shielded. Each case is unique."
- Traversable. "Our department considers 4:1 slopes and less to be "recoverable." Slopes between 4:1 and 3:1 are considered traversable, but not recoverable. Slopes greater than 3:1 are not considered traversable."
- Clear zones on roads with slopes. "Our clear zone values do vary based on whether the slope abutting the shoulder is a front slope or a back slope."

Bureau of Design & Environmental Manual

Ch. 38: Roadside Safety

<http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap38.pdf>.

- 38-3- Roadside Clear Zones [Pg. 13] -- The clear zone distances provided in this section apply to all freeway projects and to new construction/reconstruction projects on non-freeways. Figure 38-3A [Pg. 14] is a table that presents recommended clear zone distances for new construction and reconstruction. This section discusses using the table to determine the applicable clear zone.
- 38-3.02(d)- Side Slopes [Pg. 16] -- The roadway side slope will influence the recommended clear zone distance from Figure 38-3A. Figure 38-3B [Pg. 17] presents a schematic of the general side slope configurations, which may include a straight front slope, a variable or barn roof section, a section with a roadside ditch, or a section where the toe of the back slope is adjacent to the edge of shoulder.
- 38-3.02(g)- Lane Width [Pg. 22] -- The clear zone distances in Figure 38-3A are, theoretically, predicated upon a 12-foot lane width. However, they will be used for any lane width.
- 38-3.03- Front Slopes [Pg. 22] -- Figure 38-3B illustrates the two basic configurations for front slopes (i.e., straight slope or variable slope). Section 38-2 [Pg. 9] presents definitions of parallel front slopes which apply to clear zone determinations. Figure 38-3E [Pg. 24] presents schematics for these definitions. This section discusses the clear zone application in conjunction with Figure 38-3A.

Ch. 49: 3R Guidelines for Rural and Urban Highways (Non-Freeways)

<http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap49.pdf>

This chapter presents the criteria for 3R projects on non-freeways.

- 49-3.07(c)- Clear Zones [Pg. 28] -- For rural arterials other than at horizontal curves, clear zone widths (measured from the edge of traveled way) should be in accordance with Figure 49-3D [Pg. 29]. It may be warranted to expand the roadway clear zone on the outside of relatively sharp horizontal curves. This addresses the increased potential of motorists running off the roadway at curves. Figure 49-3E [Pg. 29] presents the clear zones at horizontal curves.
- 49-3.07(g)- Trees [Pg. 34] -- Trees maturing to a diameter greater than 4 inches, unless shielded by a protective device required for other purposes, shall be removed within the clear zone. Trees on backslopes that are not likely to be impacted by vehicles may generally remain in place. In cases where unusual specimens are in jeopardy, guardrail or attenuator protection may be considered as an alternative to removal.
- 49-6.07(c)- Clear Zones [Pg. 58] -- On unmarked routes on the State highway system, clear zone widths (measured from the traveled way edge) should be in accordance with Figure 49-6B [Pg. 59].

Iowa

Contact: Will Stein

Design Methods Engineer

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- Definition. "Yes, our clear zone definition applies to both. I've attached a copy of our maintenance standard for removal of vegetation."
(See attached pdf file: Iowa Maintenance Standard.)
- Run-out zones. "Yes, refer to the attached maintenance standard."
- Traversable. "Iowa follows the AASHTO Roadside Design Guide (RDG) for what we consider recoverable, non-recoverable, and critical slopes. The RDG suggests slopes flatter than 3:1 are traversable (see the discussion on page 3-2 of the RDG)."
- Clear zones on roads with slopes. "Yes. Iowa uses table 3.1 in the RDG for clear zone determination. Since there are different values for foreslopes and backslopes, a fill or cut section may affect the selected clear zone."

Office of Design – Design Manual

Ch. 1C-2: Clear Zones

<ftp://165.206.203.34/design/dmanual/01c-02.pdf>

This section provides guidelines for determining clear zones on primary highways. Within the clear zone, all slopes should be no steeper than 3:1. For freeways, expressways, super-two highways, rural two-lane highways, and transitional facilities, the designer should use Table 1 [Pg. 2 and 3] to determine the appropriate clear zone. Table 1 gives a range of allowable clear zone widths. The designer should refer to Table 2 [Pg. 4] for clear zone distances for temporary traffic control zones. Any evaluations of existing features should be based on the minimum clear zone width.

Adjustments for horizontal curves should be applied at selected locations. The clear zone should be considered for widening at curves, using Table 2, when an accident history suggests the need for additional clear zone width or when all of the following criteria are met:

- the radius of the curve is less than 2,860 feet;
- the curve occurs on a high-speed roadway (design speed of 55 mph or greater);
- the curve occurs on a normally tangent alignment (one where the curve is preceded by a tangent more than a mile in length).

Michigan

Road Design Manual

<http://www.mdot.state.mi.us/design/englishroadmanual/>

Click on Ch. 7: Appurtenances.

- 7.01.11- Current Clear Zone Criteria [Pg. 12] – The Clear Zone Distances Table [Pg. 15] presents a range of values that can be used for specific conditions. Application of the values in the Table is dependent on the extent of work and the roadway classification. The higher values should be used on new construction, reconstruction and on all freeways. When evaluating existing conditions and when designing rehabilitation

projects, we should attempt to use the higher values; however, economics, existing field conditions and other restraints may justify using the lower values. Clear zone for 3R-nonfreeway projects must be selective and generally “fit” conditions within the existing right-of-way and character of the road.

- Treatment/Consideration of Obstacles Outside the Calculated Project Clear Zone [Pg. 14] – Occasionally there may be opportunities to improve the roadside safety on a project for small cost by addressing a few obstacles outside the determined clear zone. Examples of these opportunities include when isolated trees, volunteer growth, utility poles etc. are present. Depending on aesthetic concerns, it may be possible to offer the motorist a very generous clear area (beyond that required by the Distances Tables) by simply removing or relocating a few isolated obstacles.
- B. Treatment/Consideration of Obstacles Inside the Calculated Project Clear Zone [Pg. 14] – Where the following conditions exist, it may be necessary to retain trees that otherwise would be considered for removal:
 - At landscaped areas, parks, recreation or residential areas or where the functional and/or aesthetic values will be lost.
 - Exceptional or unique trees (because of their size, species or historic value).
 - On designated heritage roads and low speed roads (including low speed urban areas).
 - At locations where cumulative loss of trees would result in a significant change in character of the roadside landscape.
 - Behind nontraversable backslopes.
 - Behind barrier curbs, particularly in low speed areas.
 - Where shrubs, and/or ornamental trees exist that would have a mature diameter of 4 inches or less at 4’-6” above ground line.
 - Where removal would adversely affect endangered/threatened species, wetland, water quality, or result in significant erosion/sedimentation problems.
- D. Curve Correction Factors Table [Pg. 16] – The Table shall be applied to horizontal curves 2° or greater. The curve correction factor shall be applied to the outside of curve only. The inside portion of the curve will be treated as a tangent section.
- E. Other Controlling Factors [Pg. 16] – The designer should note that the presence of an up-slope significantly reduces the clear zone width required. It is therefore seldom necessary to remove a tree or to shield an obstacle that is located at the top of a cut-slope if the elevation of the top of slope is approximately 5’-0” to 6’-0” higher than the edge of pavement. These situations should always be checked, however.

Click on Ch. 3: Geometrics.

3.09.03- 3R Non-Freeway Safety Considerations- (C) Tree Removal [Pg. 22] – Tree removal will be selective and generally “fit” conditions within the existing right-of-way and character of the road. The 1996 AASHTO Roadside Design Guide presents ideal clear zone distance criteria; however, these distances are not always practical in Michigan. Consequently, trees within the clear zone should be considered for removal subject to the following criteria:

- Crash Frequency. Where there is evidence of vehicle-tree crashes either from actual crash reports or scarring of the trees.
- Outside of Horizontal Curves. Trees in target position on the outside of curves with a radius of 3,000 feet or less.
- Intersections and Railroad Crossings. Trees that are obstructing adequate sight distance or are particularly vulnerable to being hit.
- Volunteer Tree Growth. Consider removal of volunteer trees within the originally intended tree line. Volunteer trees are those that have naturally occurred since original construction of the road.
- Maintain Consistent Tree Line. Where a generally established tree line exists, consider removing trees that break the continuity of this line within the clear zone.
- Clear Zone. See section 7.01.11B (cited above). Review crash history for need for spot improvements.

Minnesota

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- Definition. “Yes.”
- Run-out zones. “This depends on the slopes. See the examples shown in the Road Design Manual (on Pgs. 40 and 41).”

- Traversable. “1:4 slopes and flatter are considered traversable and recoverable and slopes from 1:3 to 1:4 are considered traversable but not recoverable. Steeper than 1:3 are neither.”
- Clear zones on roads with slopes. “Yes. See the clear zone tables (beginning on Pg. 42 of the Manual).”

Road Design Manual

Ch. 4-6.0: Roadside Elements

<http://www.dot.state.mn.us/tecsup/rdm/english/4e.pdf>.

4-6.04.02- Design Application [Pg. 36] -- Figure 4-6.04A on Pg. 37 provides the appropriate clear zone distances for various design speeds and side slopes on tangent roadway sections with an ADT greater than 6,000. Tables 4-6.04A to K, beginning on Pg. 42, present a tabulation of clear zone distances for various combinations of design speed, ADT and side slope. These values should be used on tangent sections and on the inside of horizontal curves as shown in Section 4-6.04.03 [Pg. 40] and 4-6.04.04 [Pg. 48].

Adjustments to clear zones distances are necessary where conditions other than the above “standard” exist, and include the following adjustment regarding slopes: If the roadside fill slope varies but all slopes are recoverable, a weighted average approach should be used as shown in Figure 4-6.04C [Pg. 40]. Non-recoverable slopes cannot be used in averaging slope. If slope is non-recoverable, use the steepest recoverable slope (whether it is before or after the recoverable slope) to calculate the required width of the clear zone [Figure 4-6.04D, Pg. 40].

Missouri

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“I’ve shared your request for info with our Design Division and someone will be responding to you from their perspective. As far as roadside vegetation management goes, we do not refer to the clear zone. Our policy states that trees and other hardscape features shall not be permitted within 30 feet of the nearest traveled way.”

Contact: Keith Smith

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- Definition. “Yes, MoDOT’s definition applies to both the initial construction as well as subsequent vegetative management. In the PDM’s Chapter 4-09.14 (1) [Pg. 17], MoDOT defines clear zones and links this definition to (the AASHTO) Roadside Design Guide’s Chapter 3. Our PDM states: ‘The clear zone is defined as the roadside border area measured from the edge of the pavement that is available for the safe use by errant vehicles as determined in accordance with Chapter 3 of the AASHTO Roadside Design Guide.’ In order to provide safe space for errant vehicles, the roadside vegetation must be maintained. Of course, the Roadside Design Guide links the width of the clear (zone) to ADT, adjacent slopes and design speeds. In the PDM’s Chapter 4-09.14 (2) [Pg. 18], MoDOT states that clear zones are provided for design speeds of 50 mph (80 kph) or greater, although clear zones should be considered for lesser design speeds if economically feasible.”
- Run-out zones. “No. The clear zone is to extend an adequate distance in accordance with Roadside Design Guide. Neither our PDM nor the Roadside Design Guide mandate set distances beyond the bottom of a fill slope or a backslope. It is worth noting that our PDM allows the designer to modify the clear zone’s width once accident history or accident potential is considered. The modification must be cost effective. The PDM also provides exceptions to removal of vegetation at the top of deep cuts, the bottom of high fills and in areas not conveniently accessible to maintenance equipment. See Chapter 4-08.2 of the PDM (<http://www.modot.mo.gov/business/documents/408.pdf>, Pg. 2).”
- Traversable. “Since MoDOT links its PDM to the Roadside Design Guide, our clear zone concepts align with those of AASHTO. Thus, we agree with the statement that a 4:1 slope is recoverable, as well as traversable (i.e. should not lead to overturning if the slope is smooth and free of fixed objects).”
- Clear zones on roads with slopes. “Yes. MoDOT utilizes the Roadside Design Guide’s Figure 3.1. In this figure, the clear zone’s width varies slightly depending on the presence of a cut or fill slope.”

Project Development Manual (PDM)

Ch. IV: Detail Design, Section 4-09: Miscellaneous

<http://www.modot.org/business/documents/409.pdf>

Scroll to 4-09.14 (2) [Pg. 18]- Use of Clear Zones.

The designer may choose to modify the clear zone distance obtained from the AASHTO Roadside Design Guide's Figure 3.1 or Table 3.1 for horizontal curvature by using Table 3.2. These modifications are normally only considered where accident histories indicate a need, or a specific site investigation shows a definitive accident potential which could be significantly lessened by increasing the clear zone width, and such increases are cost-effective.

Ohio

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- **Definition.** "Our Maintenance section clears vegetation from various 'zones.' Zone Two is the design Clear Zone. See Section 403 of the attached Maintenance Manual."
(See attached .pdf file: Ohio Maintenance Administration Manual Volume 2, Pg. 37.)
- **Run-out zones.** "For Landscaping issues a 50 foot tree offset for Safety Graded sections and 30' offset for Clear Zone grading, as stated in our Landscaping Guidelines (in the LDM Reference Section). To keep the ditch clear a specific mention of 20' or 10' from the ditch line is made in Sections 4.1.1 and 4.1.2."
(See: http://www.dot.state.oh.us/roadwayengineering/Publications/LDM1/LDM%20Set%20oct-29-04/ref_landscaping_aug00.pdf, Pg. 4, Sections 4.1.1 and 4.1.2.)
- **Traversable.** "ODOT calls a 4:1 a recoverable slope. Steeper than 4:1 thru 3:1 is considered a traversable slope. See Figure 600-2E of the LDM [Pg. 27]."
- **Clear zones on roads with slopes.** "Clear zones are derived from AASHTO. Figure 600-1E of the LDM [Pg. 26] shows different clear zones widths depending on various fore- and backslopes."

Location and Design Manual (LDM), Volume 1 – Roadway Design

Section 600: Roadside Design

http://www.dot.state.oh.us/roadwayengineering/Publications/LDM1/LDM%20Set%20oct-29-04/600_oct04.pdf

Scroll to 600.2 [Pg. 4]- Clear Zone.

Figure 600-1E [Pg. 26] contains recommended clear zone widths based on design speed, traffic volume and the combination of foreslopes and backslopes on the typical cross section for the roadway. The clear zone width should be increased if a site investigation indicates that doing so would significantly lessen the potential for accidents. For areas with a history of run-off-the-road accidents on the outside of curves with a degree of curvature of 2°00' or greater [radius of 900 meters or smaller], Figure 600-1E also provides a table of adjustment factors based on design speed that should be used to extend the clear zone. In these cases, the designer should ensure that the roadway has proper superelevation before evaluating the curve's effect on the clear zone.

Research

A Guide for Addressing Collisions with Trees in Hazardous Locations

NCHRP Report 500, Volume 3, Transportation Research Board, 2003

http://gulliver.trb.org/publications/nchrp/nchrp_rpt_500v3.pdf.

This guide focuses on measures to reduce the harm in tree crashes after encroachment on the roadside has occurred, such as removing trees and shielding motorists from trees. Exhibits III-5A through 5C [Pg. 21] demonstrate the relationship among tree crashes (per-mile per-year), ADT, distance of trees from the road; and "tree coverage" (i.e., percent of the roadside with one or more trees). The study was based on data for a 5,000-mile sample of mostly rural two-lane roads (Zegeer et al., 1987). Exhibit III-5B corresponds to roadway segments having tree coverage of 15 to 30 percent and average tree distances of 0 to 30 feet from the roadway under various ADT categories. Here, sections having 15 to 30 percent tree coverage between 0 and 12 feet and having ADTs above 4,000 were found to average 0.25 tree crash per mile per year. Actual values for a given section will vary, depending upon roadway geometry (e.g., roadway width, roadway alignment); traffic factors (e.g., percent trucks); and driver factors (e.g., percent of drinking drivers, young drivers). Perhaps the most important point illustrated by Exhibits III-5A through 5C is the relative infrequency of tree crashes on two-lane highways, even where traffic volumes are higher, tree coverage is significant, and the trees are close to the road. In such cases, one might expect an average of one tree-related crash per mile every three to five years.

- Appendix 12: Identifying Risks at Hazardous Locations Involving Trees
<http://safety.transportation.org/htmlguides/trees/app12.htm>
Distance of Tree from Road.

The answer to the question "How far away from the road is enough?" is elusive and varies depending on the situation. Zeigler* found that 85 percent of the trees involved in tree crashes were within 30 feet of the traveled way. The number of cases in Michigan peaked at around 10 feet. However, the distances were not

stratified by speed or variables, and the cause for peaking at a distance of 10 feet may be a function of available cross-section rather than other factors. The width of the clear zone is often at the core of the disagreements between engineers and conservation organizations. In assessing the risk of future crashes, the distance of the tree from the road is a parameter to consider, rather than a goal to achieve.

*Guide to Management of Roadside Trees, A.J. Ziegler et al., 1986 (Report No. FHWA-IP-86-17)

<http://safety.transportation.org/htmlguides/trees/assets/GuideMgmtRoadSideTrees.pdf>.

This guide provides a step-by-step approach to identify and treat higher risk roadside vegetation. The approach involves the resolution of complex legal, safety and environmental issues associated with the removal of hazardous trees from the roadside. The guide is of interest to local jurisdiction road authorities and state highway safety and maintenance engineers.

Investigation of Median Trees and Collisions on Urban and Suburban Conventional Highways in California

Sullivan, E. and Daly, J.- California Polytechnic State University, 2004

(Presented during the TRB 2005 Annual Meeting).

The California DOT (Caltrans) Traffic Operations Program invited Cal Poly to perform a study of the safety of trees planted with limited side clearance in medians of urban and suburban conventional highways. The study produced statistical relationships linking the number and severity of reported collisions and the presence of median trees. In addition to median trees, the influence of numerous other design and environmental features were considered. Median trees on urban and suburban conventional state highways were shown to be associated with increased numbers of total collisions and fatal and injury collisions, when collisions occurring on the right side of the roadway are excluded.

As part of the study an extensive literature search was performed to summarize what was known about the impacts of street trees on traffic safety and on other aspects of traffic operations and design. The full literature review appears in the interim final report. (See: Study of Safety of Trees in Narrow Medians at

<http://ceenve.calpoly.edu/sullivan/Trees/>; Phase II Final Report.) The principal findings include:

The basic lateral clearance standard to large trees of 9 meters (30 feet) used in California is typical of standards throughout the United States. This standard has been in widespread use since the 1960s¹ and it remains the side clearance recommendation of a recent federal study on vegetation control.² The supplemental Caltrans standard of 1.8 meters (6 feet) for conventional highways with posted speeds up to 35 mph is similar to an AASHTO guideline that states “in urban areas... with lower travel speeds, large trees should be kept at least 2 m. to 3 m. (6.5 to 10 feet) from the roadway edge,”³ however it is more conservative than some other published guidelines. For example, Portland, Oregon, requires medians with trees to be 2.4 meters (8 feet) wide on “urban roads” and 1.8 meters (6 feet) wide on “regional boulevards,”^{4,5} resulting in clearances much less than the Caltrans standard.

¹ Strategic Plan for Improving Roadside Safety; NCHRP Web documents, 2001,

http://trb.org/publications/nchrp/nchrp_rrd_256.pdf and http://trb.org/trb/publications/nchrp/nchrp_w33.pdf.

² Vegetation Control for Safety: A Guide for Street and Highway Maintenance Personnel; USDOT, 1992,

<http://www.fhwa.dot.gov/tfhrc/safety/pubs/90003/90003.pdf>.

³ Highway Safety Design and Operations Guide; AASHTO, 1997.

⁴ Creating Livable Streets, Street Guidelines for 2040; Metro Regional Services, Portland OR, 1997.

⁵ Draft Traffic Manual, Chapter Z- Pedestrian Refuge Islands; Batson S., City of Portland, February 2002.

Trees and Roadside Safety in U.S. Urban Settings

Bratton, N. and Wolf, K.- University of Washington, 2004

(Presented during the TRB 2005 Annual Meeting).

This study analyzes national traffic accident data to address questions relating to roadside attributes that are associated with accident incidence and severity, urban and rural spatial differences in accidents, the association between trees and roadside accident severity, and the implications for roadside planning, design and management. The analysis involved the application of descriptive, comparative and predictive modeling statistical methods to answer the research questions.

Findings Summary [Pg. 11] -- The findings from the study include:

- While there is no significant difference in tree collision rates between urban and rural areas (1.1 percent vs. 0.7 percent, respectively), there is a significant difference between urban and rural areas for collisions with all fixed objects. Of all accidents in rural areas, 6.1 percent are collisions with fixed objects, whereas that type constitutes only 3.8 percent of urban accidents.

- Trees, as fixed objects, increase the likelihood of injury in accidents.

- The majority of tree collisions occurred on undivided, two-lane roads for which the average speed limit was 52 mph.

Trees as Technology Research [Pg. 12]

While outright removal (of trees) may lead to a reduction in injurious roadside accidents, it does so without taking into account the benefits trees provide or their value to communities. The current engineering solutions are constrained by a narrow understanding of trees' potential contributions to the safety of the roadside environment and their role in its design. Trees are another roadside technology. Research about the physical properties of various trees in collisions would enable roadside design that integrates plant life as a safety feature.

This concept has been applied in a limited way in Australian urban roadsides.* The Traffic Authority of New South Wales addressed an increasing number of accidents along busy roads and in areas with accident-prone geometry by developing a tree planting policy. Minimum distances from the roadway were specified for certain types of trees, and the Authority differentiated between the physical characteristics of different tree species, namely how their physical properties related to accident outcomes. Emphasis was placed on improving driver visibility and selecting frangible (breakable) trees for stretches of road that were more prone to run-off-road accidents.

*The Tree Crash Problem – Countermeasure Programs, Rigby, K. (14th Australian Road Research Board Conference Proceedings, Pgs. 133-138), 1988.

Fatal Single Vehicle Crashes Study: Summary Report

Monash University Accident Research Centre (AU), 1997

<http://www.monash.edu.au/muarc/reports/muarc122.pdf>.

This report summarizes the findings of the Case-control Study of Fatal Single-vehicle Crashes. The cases in the study were fatal single-vehicle crashes (or crash trips) which occurred from Dec. 1, 1995 to Nov. 30, 1996 within 200 kilometers of Melbourne. The major factors contributing to the severity of fatal single vehicle crashes were: trees and poles, not wearing seat belts and pre-1978 vehicles.

Ch. 4: Crashes Involving Trees and Poles [Pg. 25].

Almost 75 percent of the crashes involved an impact with a tree or pole or both (71 percent of metropolitan crashes, 78 percent of crashes in the rest of the study area). Trees and poles were involved to the same extent in metropolitan crashes but trees were much more common in crashes in the rest of the study area. Overall, 53 percent of the trees and 36 percent of the poles impacted were on the right of the direction of travel of the vehicle.

- 4.1- Distances to Impacted Trees and Poles -- Figure 4.1 summarizes the distances from the closest edgeline to impacted trees and poles. It shows that many of the trees impacted were between 3 meters and 10 meters from the travel lane. Eleven trees and 12 poles were less than 3 meters from the edgeline. Seven trees and nine poles were less than 2 meters from the edgeline. In the metropolitan area, crashes involving poles were more frequent. Poles were often less than 2 meters from the edge of the road. The distances to trees varied. In the rest of the study area, many more crashes involved trees than poles. Most trees were within 3 to 10 meters of the edgeline. In 65 percent of crashes where a tree was impacted, it was on the right.

MAINTENANCE STANDARD

IOWA DEPARTMENT OF TRANSPORTATION

Highway Division Office of Maintenance

APPROVED BY: Lee Wilkinson, Maint. Office Director

ORIGINATION DATE: July 1, 1975

REVISION DATE: July 1, 2003

FUNCTION TITLE: Brush and Tree Control
FUNCTION CATEGORY: ROADSIDE

FUNCTION CODE: 647

WORK PROGRAM CATEGORY: Special Authority

DESCRIPTION & PURPOSE:

All operations associated with the removal of undesirable brush/trees from the right-of-way to maintain sight distance, dispose of dead and diseased trees, and enhance scenic beauty of the right-of-way.

Includes stump removal, brush chipping, transplanting, or chemical treatment of cut stumps.

LEVEL OF MAINTENANCE (Quality Standard):

Dead trees in the right-of-way should be cut and the stumps removed. Remove all volunteer trees, sprouts, or stump growth from the roadway foreslope or from the established clear zone as per the following table, whichever is greater:

		TRAFFIC VOLUME, ADT			
Foreslope		<u>under 750</u>	<u>750-1500</u>	<u>1500-6000</u>	<u>over 6000</u>
3:1 or steeper	*16'-18' beyond the toe of foreslope or 20'-24' from edge of traveled way whichever is greater	*20'-24' beyond the toe of foreslope or 26'-32' from edge of traveled way whichever is greater	*26'-30' beyond the toe of foreslope or 32'-40' from edge of traveled way whichever is greater	*30'-32' beyond the toe of foreslope or 36'-44' from edge of traveled way whichever is greater	
4:1	20'-24'	26'-32'	32'-40'	36'-44'	
6:1 or flatter	16'-18'	20'-24'	26'-30'	30'-32'	

Trees beyond this to the right-of-way line should be permitted unless they restrict sight distance, interfere with traffic or restrict drainage. Young trees in this area should be thinned to 25 ft. spacing. All shrub growth should be preserved unless it interferes with sight distance, causes undesirable snow drifting or otherwise interferes with traffic. All trees growing on the foreslope or that create drainage problems in roadside ditches should be removed. The Highway Maintenance Supervisor shall approve the removal of large live trees in the clear zone. Any stumps being left should be cut to no more than 3" above the surface of the ground and the stump chemically treated, if necessary, to prevent regrowth. *Since recovery is less likely on 3:1 foreslopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of errant vehicles may be expected to occur beyond the toe of the slope. Determination of the width of the recovery area at the toe of the 3:1 slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and accident histories. The distance as noted beyond the toe of the foreslope in the table above may be reduced by the width of the existing shoulder.

SCHEDULING GUIDE: Normal monthly accomplishment as a percent of total program.

<u>JUL</u>	<u>AUG</u>	<u>SEP</u>	<u>OCT</u>	<u>NOV</u>	<u>DEC</u>	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>	<u>APR</u>	<u>MAY</u>	<u>JUN</u>
4	3	6	5	5	11	12	15	15	14	8	4

Accounts for 1.2% of total maintenance hours.

PERFORMANCE STANDARD

FUNCTION: 647

RECOMMENDED PROCEDURES:

Provide traffic control as needed.
Refer to Appendix A to select the proper traffic control plan.
Code traffic control to Function 673.
Methods and Procedures dependent upon work being performed.

Only certified applicators may apply herbicides.

1. Review safety precautions before cutting trees or transplanting.
2. Outline areas to be cut or transplanted.
3. Cut brush or trees and remove or dispose of brush and limbs properly.
4. Treat stumps with herbicide, or remove with stump cutter.
5. Use caution to prevent contamination of non-target areas.

Review Right-of-Way contracts for covenants and obtain permission from property owner to cut trees where right-of-way is by easement.

Reference: Utilities on the Primary Road System (Section 3-4)
Refer to Safety Page for required/suggested Personal Protective Equipment

MATERIALS:

Herbicide	Bar oil
Diesel	2-cycle oil
Gasoline	

Refer to MSDS for all materials used

RECOMMENDED CREW SIZE:

1 - Chain Saw/Brush Cutter Operator
Certified Applicator (as needed)
Additional Crew as Needed

RECOMMENDED EQUIPMENT:

Tree Spade (as needed)	Backpack sprayer (as needed)
2 - Trucks	
Brush Chipper (as needed)	
Stump Cutter (as needed)	
Chain Saw(s) (as needed)	
Hand Tools as Needed	

Other equipment may be necessary in removal of large trees.

Refer to Operators Manual for all equipment

ACCOMPLISHMENT:

Unit: Hours

Standard Rate: N/A

Daily Production: N/A

Safety Page

Function Code: 647

Origination Date: July 1, 2003

Revision Date: _____

[illegible]

Maintenance Administration Manual Volume Two

May 2004

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400.1 Introduction

Vegetation management is performed to ensure the safety of the motorist – providing clear sight distance at intersections and curves, unobstructed road signs, and clear guardrails. Obstructed road signs and sight distance issues are more than a nuisance to the driver, they are safety hazards. Vegetation management efforts are therefore a key aspect of the ODOT maintenance program.

Tree and brush cutting, mowing, and herbicide applications are tools used to maintain and control the growth of different types of vegetation. Integrated Vegetation Management (IVM) is an ongoing dynamic program that combines and utilizes different methods, evaluation, and control into one program that causes different effects within maintaining vegetation. A good IVM program uses information about the vegetation desired to be controlled, considers the desired results, weather conditions, cost, and other important factors. A management plan is then established using various control methods. An example: A tree is discovered blocking a sign along a guardrail. It is first determined the tree is a maple tree. The desired result is to remove the tree from blocking the sign. Herbicides will kill the tree but not remove it. It is also established that maple trees are prone to regrowth if not treated with a cut stump herbicide after being removed. The task must be performed when rain is not in the immediate forecast. Traffic control needs to be set up. It is determined the cost of the operation will be acceptable. A good plan will save labor, time, and money.

Effective vegetation management controls the spread of undesirable woody plants and noxious weeds while providing habitat for ground nesting birds and small animals. Vegetation management helps prevent drainage obstructions and maintains ditch visibility.

Effective vegetation management also provides the motorist with a uniform and attractive roadside.

400.2 Statutory Authority

§5501.42	<i>Cutting trees and roadside vegetation</i>
§5516.14	<i>Authority to permit cutting of vegetation near lawful signs</i>
§5529.11	<i>Authority to permit vegetation planting by landowners</i>
§5529.12	<i>Authority to plant trees</i>
§5579.04	<i>Roadside vegetation control</i>
§5579.08	<i>Cutting of brush, briers, and noxious weeds</i>

400.3 Clearance for Advertising

Removing, trimming, cutting, spraying, etc. of vegetation along the right of way for the express purpose of increasing advertising, viewing of business development and/or clearance of billboards is not encouraged. Only in special circumstances is this activity allowed. If a request is made of the Department, review of the proposal shall be made by the District Highway Management Administrator, County Manager and/or Roadside Supervisor. If determined to be a valid proposal, an M&R 505 permit is required. Permittee shall follow M&R 505 beautification specifications.

401 Definitions

401.1 Vegetation

Undesirable Vegetation:

Any plant, regardless of size, species, or annual/perennial designation, that is growing where it isn't wanted, and could cause damage to the road surface, create traffic hazards, etc.

Desirable Vegetation:

In the highway right-of-way; this is typically grass. Areas set aside for regeneration of trees, shrubs and wildflowers may prosper if there is sufficient right-of-way in the area.

401.2 Fall Zone

The fall zone is the area in close proximity to the roadway, where existing vegetation or trees are large enough to fall and become a hazard to traffic.

401.3 Herbicide

Herbicides are chemicals that control plants by changing normal growth or cause elimination. *Selective herbicides* are used to control or kill specific undesirable plants, but do no harm to desirable plants. *Non-selective herbicides* are used to kill all vegetation, regardless of species, and may leave the soil sterile (nonproductive) for a year or more. This depends on the specific chemical and the rate of application. A herbicide is a pesticide, by definition.

401.4 Pesticide

Pesticide is a general term used when referencing all herbicides, fungicides, etc.

401.5 Noxious Weeds

Noxious weeds are plants designated by the Director of the Department of Agriculture for the Ohio Noxious Weed List. Such plants possess one or more of the following undesirable attributes:

- Is in aggressive competition with economic crops or native plant communities
- Has toxicity to livestock
- Is a carrier of detrimental insects, diseases or parasites
- Is directly or indirectly detrimental to environmentally sound management of natural or agricultural ecosystems

401.6 Vegetation Obstruction (OPI)

A vegetation obstruction is any vegetation growth that obscures signage, causes sight distance problems, or appears around guardrail. Vegetation obstructions are recorded annually by a Central Office maintenance quality survey team and are part of the organizational performance index. The observation scope is roadsides and medians.

401.7 Mowing

Mowing is a mechanical method of vegetation management. Mowing is the traditional maintenance method for controlling the growth of undesirable woody plants, noxious weeds, and grass.

401.8 Shadow Vehicle

A shadow vehicle is part of a moving operation and is used within the traffic control zone to provide advance warning to traffic, or to guide traffic into the proper lane by the use of signs or a flashing arrow panel.

401.9 Habitat

Habitat refers to an area where vegetation is allowed to grow creating grass, shrub, or tree cover for birds, animals, or native plants.

401.10 Integrated Vegetation Management

Integrated Vegetation Management (IVM) is an ongoing dynamic program that combines and utilizes different methods, evaluations, and controls into one program that causes different effects within maintaining vegetation.

402 Eliminating Vegetation Obstruction (OPI)

402.1 Identifying Vegetation Obstruction

There are different methods used to identify where routine vegetation management needs to occur. One is the Maintenance Quality Survey (MQS) evaluation. The central office MQS team identifies vegetation obstructions and records them as deficiencies. The information is then conveyed to the County Manager. Another method of identification occurs through County Manager, Transportation Manager, and Highway Worker inspections. All roads are to be inspected at least twice a month. Any identified obstructions are to be recorded and placed on the maintenance schedule.

402.2 Clearing Vegetation Obstruction

ODOT clears vegetation obstruction so that motorists have a clear view of signs, unobstructed view around curves, and are able to observe fixed objects such as guardrail or drainage structures along the roadway. It is important for drivers who lose control of their vehicle to have a clear sight path of objects along the roadside as they regain control of their vehicle. Keeping vegetation clear also provides an open area for a motorist in distress to fix a flat tire or pull off to the side of the road to wait for help.

Vegetation obstructions can shade signs and roadways and delay the time it would take for snow and ice to melt or for a wet roadway to dry. Slow drying times can cause the roadways to deteriorate more quickly because the presence of moisture during low temperatures causes freezing and thawing action. Vegetation obstruction is addressed in the Maintenance Quality Survey Manual, the Preventive Maintenance Policy, and the ODOT Construction and Materials Specifications Book.

403 Vegetation Management Zones

Roadways are divided into four vegetation management zones, with each zone having specific maintenance requirements: Vegetation Free, Operational, Transition and Undisturbed. Each zone is described in detail below:

403.1 Zone One: Vegetation Free Zone

This zone is the shoulder area. This area is kept free of all vegetation to:

- Allow for surface drainage
- Provide visibility and maintenance of roadside hardware
- Prevent pavement breakups by invasive plants
- Provide sight distance for passing, stopping, and at intersections

403.2 Zone Two: Operational Zone

This zone is also called the safety recovery zone; it begins where Zone One ends. Zone Two width can vary depending on the width of the right-of-way, but is typically 30 feet along interstate and divided highways. This area is managed to:

- Provide a clearly visible area for vehicle recovery
- Provide sight distance for stopping on curves and at intersections
- Maintain visible and clear ditches
- Eliminate hazardous trees and tree canopy shading pavement
- Control weeds
- Prevent erosion
- Accommodate underground utilities
- Enhance visual quality

403.3 Zone Three: Transition Zone

This zone requires selective vegetation management. It is far enough away from the travel lanes so that tall trees will not fall onto the road. Management of this zone may also:

- Promote low maintenance plant communities
- Blend and/or screen adjacent surroundings
- Control noxious weeds
- Prevent erosion
- Maintain and enhance visual quality
- Preserve wetlands and wildlife habitat
- Accommodate utilities
- Preserve or conserve native plants and wildflowers

403.4 Zone 4: Undisturbed Zone

In this zone vegetation management can be dictated by surrounding property, such as farmland or wood lots. Manage Zone 4 to ensure that the vegetation present is not detrimental to neighboring land use.

404 Brush Cutting

Brush and foliage management ensures adequate sight distance is maintained, highway signage is visible, and that canopy shading of pavement is kept to a minimum. Any hazardous, dead or diseased trees located in the fall zone of the right of way should be removed and, where applicable, cut stump herbicide should be applied.

404.1 Brush Removal

Hand Removal of Brush & Vegetation

What are the hazards?

1. Chain saws, sharp-edged tools, poison ivy, insects, thorns, large clumps of brush, slips, trips and falls on uneven ground, overcrowding of workers, moving equipment, utility lines and traffic.

What do we need to know before we leave the garage?

1. Pre-trip your assigned truck and any additional equipment to be used on the job.
2. Determine what kind of traffic control is needed and make sure it is loaded up.
3. Have the necessary personal protective equipment which includes a good pair of work gloves.
4. Hard hat, ear protection, eye protection, and chaps are required for chain saw use.
5. Dress appropriately for the weather. It's a good practice to wear long sleeve shirts and high top leather boots if you're going into high grass and weeds.
6. Have plenty of cold water available for hot weather work.

What should we do out on the job?

1. Park in an area that provides safe entrance and exit of the work area. Don't create a potential conflict with other work vehicles or the traveling public.
2. Be aware of escape routes in case of an emergency. It's a good practice to face oncoming traffic while on foot.
3. Look for loose materials, tripping hazards, uneven ground, slippery surfaces, and areas where equipment is operating. Remember that if you can't see the operator, the operator can't see you.
4. Chain saw, bucket truck, and chipper operators must be trained to do the job.
5. Use caution when handling tools with sharp edges. Gloves are required when sharpening tools.
6. Allow ample space for everyone to work safely. Don't bunch up. Stay clear of chain saws unless you're the operator or the helper.
7. Don't cut limbs that may contact overhead utility lines.
8. Tree trimming which would require climbing must be performed only by a trained employee or with the use of a bucket truck. Proper fall arrest and safety equipment must be used.
9. Use extreme care when cutting trees and brush that are under stress such as conditions following an ice storm.
10. Cut and stack limbs and brush in manageable pieces that are easily handled to avoid back injuries.
11. Use a front-end loader to move logs and large pieces of cut-up materials.

404.2 Chain Saw Safety

Safety With Chainsaws

What should you do to prepare your saw for cutting?

1. Check the chain's condition and sharpness. A sharp chain makes the saw easier to use.
2. Check the chain tension. If it is too loose, it may derail and cause a severe injury. If it is too tight, it may bind and also cause an accident or damage to the saw.
3. All nuts and screws should be tight. Everything should be well lubricated.
4. Fuel in a safe place. Wipe up spills and take the saw to another location before starting.

What about the work site conditions?

1. If you're cutting down a tree, make sure you consider which way the wind is blowing and look for a lean in the tree or if there are several very large limbs on one side of the tree.
2. Make sure that you have secure footing and stand at a 45 degree angle when cutting limbs to prevent the saw from striking your leg if it slips.
3. Plan an escape route. Make sure there are no obstacles and figure to have at least 25 clear feet of space at a 45 degree angle.

What clothing should you wear?

1. Snug fitting with complete freedom of movement. No jewelry, baggy sleeves, cuffed pants or long hair that could get caught in a chain saw.
2. Heavy duty no-slip gloves. Face screen, shield or safety goggles, hard hat, ear muffs or plugs and chaps to protect your legs from severe cuts should the chainsaw slip.

What's the big deal about kickback?

1. Kickback happens when a force throws the saw rapidly and sometimes uncontrollably towards you. The saw may have hit a knot, the tip of the chain strikes a nearby limb, the saw is running too slowly, the operator is twisting the saw in the cut, using a dull or loose chain, or a loose grip on the saw or cutting with only one hand.
2. Prevent kickback by always holding the saw firmly with both hands. Keep the left arm straight. Use a saw with a chain brake or anti-kickback device.
3. Cut with the lower part of the blade, not with the tip or nose. Keep a high speed when entering, cutting and leaving the wood. Keep the chain sharp.
4. Never cut above your chest.

What jobs are not for you and your chain saw?

1. If possible, have a buddy with you so you won't have to work alone but NEVER allow someone else to hold the wood while you cut.
2. You should always reposition logs between cuts, not while the chain saw is still running in your hand.
3. Use caution when cutting small flexible branches or brush with a chain saw. Their size and flexibility can easily cause the saw to bounce or bind up. A hand saw, pruning shears, or an axe can be used instead.

405 Chemical Vegetation Management

405.1 Pesticide Applicator's License

A pesticide applicator must be licensed as public operator in category 5, *Industrial Vegetation Control*, when performing pesticide applications while employed by the Department of Transportation.

405.2 Trained Serviceman Applicator

Trained Serviceman applicators must meet or exceed Ohio Department of Agriculture requirements for this category. This person, after receiving training in the classroom and in the field, works under direct supervision of the licensed applicator. This applicator is similar to the certified licensed applicator, but does not hold a license. A signed training statement for the trained serviceman must be kept in the employee's file.

405.3 Chemical Spray Application

■ Restrictions

The use of herbicides should be restricted to:

- areas specified on the label of the herbicide
- areas where total vegetation control is desired

■ Drift Control

A spray additive should be used to control drift.

■ Crop Sensitive Areas

Special care must be taken to ensure that herbicide application is not performed adjacent to highly sensitive crops, such as grapes, tobacco, soybeans, tomatoes, etc.

■ ‘DO NOT SPRAY’ Signs

Herbicides are not to be applied where an ODOT ‘Do Not Spray’ sign is erected or a sign is posted by a private property owner.

■ Total Vegetation Control

Where non-selective herbicide is used to eliminate vegetation under a guardrail, around signs or other appropriate areas, extreme care must be taken not to over-spray. When spraying guardrail, the spray should be applied in a uniform swath of sufficient width, more than 6 inches behind the guardrail post, to control the vegetation in front of, under and behind the guardrail post.

In areas prone to erosion; do not kill all the vegetation between the edge of the pavement and the back of the posts. Areas prone to erosion should also have a grass filter strip between the edge of the pavement and the front of the guardrail.

Care must be taken not to create erosion problems through use of total vegetation control practices.

■ Record of Application

All pesticide applications are to be recorded on form M&R 629, *Daily Pesticide Report*, and kept on file for three years at the county garage.

■ Safe Operation

Drivers and applicators are required to properly apply and control the material and to operate safely with the traveling public.

406 Mechanical Vegetation Management

406.1 Mowing Cycles

The Department of Transportation commences mowing operations each year when the vegetation reaches a minimum height of twelve inches. Rights of way are typically mowed before each major traveling holiday: Memorial Day, the Fourth of July and Labor Day. A final mowing can occur in late September or October to remove any unwanted vegetation and prepare the right-of-way for winter. Additional cuttings in the operational zone may be required if excess rainfall makes the cool season grasses grow above and beyond normal.

406.2 Mowing Height

Mower cutting height is set to avoid contact with debris, rocks, etc. This height is usually six to eight inches. Some right-of-way which adjoins a community is cut to satisfy the public's desire for a roadside landscape similar to that of the surrounding vegetation. Cutting height is usually set at four inches and the frequency of cutting can also be increased.

406.3 Mowing Equipment

All tractors shall be equipped with the following:

- Strobe, cateye or beacon lights, mounted at the highest point and in working condition.
- Shall have a back-up alarm when the operator's view is obstructed to the rear.
- An orange or red safety flag on a flexible pole, shall be mounted on the left rear of the tractor, and shall be at least 8 feet from the ground to the bottom of the flag. Tractors 8 feet or higher and equipped with 4-way flashers do not require a safety flag.
- Slow moving vehicle emblem mounted and visible from 500 feet distance.

406.4 Signing for Mowing Operations

1. The MOWING AHEAD sign is to be used where the mower must operate with any portion of the mowing equipment on or over the traveled way during the mowing operation.
2. Below are some examples of conditions for which MOWING AHEAD signs are needed, but are not to be interpreted as the complete listing of all conditions:

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- Narrow roadways where equipment must remain on the pavement in order to mow shoulder or side slope areas.
 - Where equipment must use the traveled way to detour around objects such as guardrail, steep slope areas, mailboxes, signs, etc.
 - Bridges or underpasses that do not have sufficient shoulder width to accommodate passage of mowing equipment without encroaching on the traveled way.
3. Geometric conditions that could produce unexpected hazards or traffic conflicts such as:
- Sharp vertical or horizontal curves or
 - Multi-lane highways where mowers must cross the traveled lanes to reach median or shoulder areas.
4. MOWING AHEAD signing shall also be used where a shadow vehicle is used based on the criteria listed below for SHADOW VEHICLES.
5. When mowers are in transit on the highway at speeds greater than 25 miles per hour, the MOWING AHEAD sign is not required.
- When the MOWING AHEAD sign is used on multi-lane highways, the 48-inch size should be used. 36 inch signs may be used on multi-lane highways if the cross section of the roadway makes it impractical to use 48 inch signs.
 - On all other highways the 36-inch size shall be used.
6. The MOWING AHEAD sign shall be located not less than 500 feet in advance of the mowing operation, but the distance between the MOWING AHEAD sign and the mowing operation shall not exceed 5 miles. If the work area exceeds 5 miles in length, additional advance warning signs should be provided at intervals of no more than 5 miles. On divided highways, the sign shall be placed on the same traveled way as the mowing operation.

406.5 Shadow Vehicles for Mowing Operations

Shadow vehicles will be required when **any** of the following criteria are met:

- Narrow berm width so that the tractor is consistently in the traveled lanes while mowing.

- The section has no passing lines on at least 90% of its length as determined from the logs in the District Traffic Office.
- The section has at least 1500 vehicles a day or at least 15% B and C type trucks in the current Traffic Survey Report.

The shadow vehicle will be equipped with cat eye or strobe lights such as are on the dump trucks and will display on the rear AC-35A-48 “SLOW TRACTOR AHEAD” sign. This vehicle will stay highly visible by varying the distance between it and the mower as the mower goes over hill crests or around curves.

A record of sections which require the use of a shadow vehicle for mowing shall be established and maintained in each county facility for use by the County Manager and Highway Workers.

406.6 Roadside Mowing Tips

What’s the problem?

1. Driving tractor mowers at high speeds can result in accidents because of the risk of overturning. Quick maneuvers can also cause a rollover as does using the brakes while turning.

What do we need to know about driving to the work area?

1. Be sure the tractor has a slow-moving vehicle sign as well as working lights and warning flags.
2. If the mowing attachment doesn’t have its own brake system, it’s important to keep a safe and slow speed. Avoid very sharp turns since they can cause attachments to jackknife.
3. Always let traffic clear and make sure you have enough time to cross a highway.
4. Bat-wings should be raised and secured before driving on the road.

What should we do about safety in the work area?

1. Before starting, make sure mowing ahead signs are in place, no more than 5 miles apart.
2. Be alert for rough ground, hidden objects, culvert holes, hidden rocks, tree stumps and utility boxes.
3. If you get stuck in a ditch, don’t rev the engine and pop the clutch. Try backing out. If you can only go forwards, you may have to dig out in front of the rear wheels and use a low gear while letting out the clutch slowly and applying the brake on the spinning tire.

What about operating on slopes?

1. When starting up a hill, let the clutch out slowly. Popping it can cause the mower to tip backwards. You might even want to back up the hill.
2. If the tractor does start to tip, steer the front wheels downhill to increase stability and help prevent an overturn.
3. Keep the tractor in gear while going downhill and let the engine act as a brake to slow it down. Use both brake pedals if necessary and never take the tractor out of gear.

407 ODOT References

Roadside Vegetation Management Policy

The Roadside Vegetation Management Policy 512-002(P) is accessible on the ODOT intranet at <http://intranet.dot.state.oh.us/policy/default.htm> The vegetation policy is listed under “Highway Operations.”

Pesticide Information

Ohio Department of Agriculture (pesticide) website:
<http://www.ohioagriculture.gov/pubs/divs/plnt/curr/pr/plnt-pr-index.stm>

Investigation of Median Trees and Collisions on Urban and Suburban Conventional Highways in California

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Abstract. This study examined the safety of large trees in curbed medians of conventional highways that are also principal streets in developed urban and suburban areas. Statistical modeling methods were used to associate collision frequency and severity with highway and traffic characteristics, with and without median trees. The methods include simple accident rates and three types of multivariate modeling, using collision data for six years. The analysis was done in two parts. The first part was a screening investigation of pertinent facilities under both state and local jurisdiction. The second part, described here in detail, focused on 14,283 collisions occurring on 58 miles (99 kilometers) of designated state highways in 29 different sections, 19 with median trees. The analysis examined different subsets of reported collisions, in turn omitting collisions on the right side of the road, collisions not having median or median-shoulder involvement, and collisions at intersections. The overall conclusion is that large trees in medians of major conventional urban and suburban state-jurisdiction highways are associated with more collisions and increased severity. However, some of these associations are statistically weak. For the situations examined, lower speeds and larger side clearances were not found to mitigate the increased collision impacts associated with median trees.

INTRODUCTION

The California Department of Transportation (Caltrans) Traffic Operations Program invited the California Polytechnic State University (Cal Poly) to perform a study of the safety of trees planted with limited side clearance in medians of urban and suburban conventional highways. The motivation was the need for improved evidence concerning safety impacts in light of increasing local requests to plant median trees along state highways that are also principal arterials in developed urban areas. The study produced statistical relationships linking the number and severity of reported collisions and the presence of median trees. In addition to median trees, the influence of numerous other design and environmental features were considered.

California's current setback standards for trees along conventional state highways appear in Section 902.3(4) of the Caltrans *Highway Design Manual*. The manual states that "large trees that at maturity (10 years) will have a trunk 100 mm. or greater in diameter (measured 1.2 m. above the ground) are not permitted unless all of the following conditions are met:

- "The existing speed zone is 56.3 km/hr (35 mph or less).
- "There is a curb or barrier between the traveled way and the trees.
- "The sight distance is not restricted.
- "Existing signs and signals are not visually restricted.
- "In a median the trees are at least 1.8 m. from the face of curb.
- "Trees are at least 30.4 m from the end of any median strip and at least 6 m from any manholes.

"If all the above conditions are not met, the locations of large trees must provide a minimum of 9 m. clearance from the edge of traveled way." (1). A conflict occurs because many urban arterials targeted for beautification in developed urban and suburban areas of California are posted more than 35 mph (56.3 km/hr) and many medians along urban roadways cannot accommodate the required 1.8 m. (6 foot) setback to trees even where speeds are low. For posted speeds over 35 mph (56.3 km/hr), the 9 m. (30 foot) setback requirement essentially prohibits median trees.

There are a number of reasons why trees in medians of conventional urban highways could possibly affect collision frequency and severity, either for better or worse. Possible impacts related to severity include:

- Trees increase the number of concentrated and unyielding objects available to hit.
- Tree-hits are generally more severe than collisions with other objects.
- Some head-on & broadside collisions may be replaced with hit-object collisions.
- Trees may reduce pedestrian visibility, leading to more hit-pedestrian collisions.

Effects related to collision frequency include:

- Trees may reduce visibility (to pedestrians/other vehicles).
- Detritus may reduce road surface friction.
- Trees may increase debris in the roadway.
- Roots may contribute to uneven road surfaces.
- Trees may increase the percentage of collisions reported (due to greater severity).
- Trees may obscure visibility to signs/signals.
- Trees may change patterns of sunlight, thereby affecting visibility either for better or worse.
- Risk to road crews may increase due to more median maintenance activity.
- Trees may help reduce aggressive driving (traffic calming effect).
- Trees may improve drivers' orientation and lane keeping (channelization effect).

A staged approach was taken to performing the statistical analysis. Initially, a data set of 65 divided conventional highway sections throughout California was used to explore broad cross-sectional relationships for six years of reported collisions, 1996 through 2001. About half the selected sections have median trees, while the sections without trees have various median types, both curbed and uncurbed medians, the latter including many that permit continuous left turns. The initial statistical analysis addressed all the collisions reported anywhere on the selected sections and included both state highways and similar roadways under local jurisdiction. The local jurisdiction sections were included initially because of concern that there would not be a sufficient number of conventional state highway sections with median trees to perform an adequate statistical analysis. The findings of this work were presented in an initial final report. (2)

Findings from the initial work suggested further in-depth analysis to address remaining concerns. The second stage of the work used a data set of 29 conventional state highway sections with only curbed medians, about two-thirds containing median trees. These sections include nearly all of the conventional urban highway sections in the state having homogenous characteristics along a mile or more of highway, considered necessary for statistical stability in the data. The complete data set of 14,283 reported collisions during six years was partitioned into subsets of collisions that were modeled separately. The key subsets include 9,587 collisions with right-side-only collisions removed, 6,170 with both right-side-only and intersection collisions removed, 2,354 specifically involving the median or median-shoulder, and 839 involving the median or median-shoulder and excluding intersection collisions. Many simple accident rate models and non-linear multivariate models were fit to these data sets, as described in the later sections presenting the analysis approach and findings, and in the final study report. (3)

LITERATURE REVIEW

When the opportunity arose to investigate the safety impacts of median trees in urban and suburban settings, there was concern whether or not additional research was actually needed. Highway clear-zone guidelines have existed for a long time, and these guidelines are well supported by considerable statistical and laboratory research. Past research and the experience of many highway safety officials clearly show roadside trees to be critical hazards, since trees are typically hard unyielding obstacles with shapes that often penetrate vehicles unfortunate enough to hit them.

Given this background, an extensive literature search was done to summarize what was known about the impacts of street trees on traffic safety and on other aspects of traffic operations and design. The full literature review appears in the interim final report. (2) Some principal findings are identified below.

The basic lateral clearance standard to large trees of 9 meters (30 feet) used in California is typical of standards throughout the United States. This standard has been in widespread use since the 1960's (4) and it remains the side clearance recommendation of a recent federal study on vegetation control. (5) The supplemental Caltrans' standard of 1.8 meters (6 feet) for conventional highways with posted speeds up to 35 mph (56.3 km/hr) is similar to an AASHTO guideline that states "in urban areas... with lower travel speeds, large trees should be kept at least 2 m. to 3 m. (6.5 to 10 ft.) from the roadway edge," (6) however it is more conservative than some other published guidelines. For example, Portland, Oregon, requires medians with trees to be 2.4 m. (8 ft.) wide on "urban roads" and 1.8 m. (6 ft.) wide on "regional boulevards," (7, 8) resulting in clearances much less than the Caltrans standard.

The safety problems of roadside trees along high speed, rural roadways are well established, with numerous studies citing dramatic findings, for example, that trees "are involved in only 25% of the fixed-object accidents, but are responsible for approximately 48% of the fatalities." (9, 10, 11, 12) However, Zeigler's much cited 1980's research in Michigan regarding trees and safety found that fatalities were associated mostly with the largest trees with trunks greater than 500 mm (20 inches) in diameter. However, again, this finding applies specifically to rural conditions. (13)

Conflicts exist between the only two previous empirical studies found that specifically address the safety of trees along urban highways. A 1990 investigation by Turner of collisions involving trees in Huntsville AL (14) concluded that collision characteristics are similar to those found in rural conditions, while a more recent international investigation of selected boulevards by Jacobs *et al* found little difference between accident rates on major urban tree-lined boulevards and similar urban control sections without trees. (15, 16)

Some investigators argue that safety is best served by selective tree removal or installing protective devices at critical locations, such as along the outsides of curves and where experience otherwise indicates there are problems. (17, 13, 18, 19) Published guidelines exist for selective tree control to eliminate the most problematic of tree impacts on highway safety. (5, 20)

On the other side of the issue, positive safety impacts have been claimed for trees, including their ability to improve delineation of the highway edges, thereby reducing encroachment into medians (21), to reduce headlight glare from oncoming vehicles, to reduce runoff (22, 23), and to reduce speed. While the speed reduction effect is usually discussed on an anecdotal basis (24, 25, 26, 27), some empirical evidence exists. (28)

The conclusion of the literature review is that there was insufficient evidence to conclude that the well-established safety problems of nearby trees along rural highways also always apply to major conventional highways in built-up urban and suburban settings. Thus, additional empirical analysis was performed.

APPROACH TO THE ANALYSIS

This section and the next focus on the statistical analysis performed for California state highways. For details on the earlier analysis involving local-jurisdiction roadways, see the interim final report. (3)

For conventional state highways with medians in urban/suburban settings, other characteristics, such as roadway widths, lane widths, median widths, setbacks, traffic volumes, speeds, and surrounding development, vary widely. The state's Traffic Accident Surveillance and Analysis System (TASAS) was used to identify all highway sections in California having the desired characteristics. Suitable sections were defined as those where geometric and traffic features remain mostly the same for about a mile or more. It was believed that study sections should be at least this long to avoid large random variation in collision counts relative to the average. Suitability of sections was verified by site visits during which additional measurements were obtained. Site visits resulted in some sections being eliminated and in sometimes finding additional suitable sections. Some candidate sections were also eliminated where it was found through contacts with local officials that median trees or other section characteristics changed appreciably during the six-year coverage period of the collision data.

The final data set for state highways contains 29 individual sections with considerable variation in characteristics. Table 1 lists all the variables used to characterize each section. Variables marked with asterisks entered at least one of the models published in the study report. Other variables were tested but were found to be either uncorrelated to left-side collisions or correlated with other variables. Table 2 shows how the values of key section characteristics compare between the sections with median trees and the sections without. On average, the sections with median trees are longer, narrower, a little slower, carry less traffic, and have wider medians. These comparisons suggest a bias toward sections with trees possibly being safer, except for the longer average section length, which could cause sections with trees to have more intersections, where collisions concentrate. The last row of Table 2 shows that the average six-year exposure per section, based on six years of traffic data, is around 185 million vehicle-miles - MVM (300 million vehicle-kilometers - MVK). At this level of exposure, assuming an actual average rate of 1 accident per MVM (0.62 accident per MVK) and assuming that collision counts behave randomly following the Poisson probability distribution, it should be possible to estimate the accident rate of the average section within 15% of the true rate, with 95% confidence. This was considered suitable for statistical modeling.

Certain potentially pertinent section descriptors were not considered, which can be viewed as a limitation of the present analysis. Future such investigations should attempt to include such measures, in some cases requiring the development of reasonable quantification methods. Such descriptors include better characterization of access points such as intersections and busy driveways with regard to turning movements and types of control. Also of interest are the species of trees and the characteristics of planting patterns, such as the number of rows and linear density.

The dependent variables in the multivariate modeling include total reported collisions, fatal and injury (F&I) collisions, and the ratio of F&I to total collisions. The models were fit to four different subsets of reported collision data, which either excluded collisions with right-side-only involvement or included only collisions with median or median-shoulder involvement, in both cases with and without collisions at intersections. A number of simple single variable accident rate models were also developed.

Three types of multivariate generalized linear model forms were used, typical of mathematical relationships used in previous accident modeling. These model forms were fit to the different subsets of collision data:

- Model GL-1: $COLL_i = (\epsilon^{\beta_0 + \beta_1 L_i + \beta_2 ADT_i + \beta_3 MEDTREE_i + \beta_4 X_{i1} + \beta_5 X_{i2} + \dots}) ERR_i$
(The GL-1 error term ERR_i is assumed to follow the negative binomial distribution.)
- Model GL-2: $COLL_i = L_i ADT_i (\epsilon^{\beta_0 + \beta_1 MEDTREE_i + \beta_2 X_{i1} + \beta_3 X_{i2} + \dots}) ERR_i$
(The GL-2 error term ERR_i is assumed to follow the Poisson distribution.)

- $$\left(\frac{COLL_i^{F\&I}}{COLL_i^{ALL}} \right) = (\varepsilon^{\beta_0 + \beta_1 MEDTREE_i + \beta_2 X_{i1} + \beta_3 X_{i2} + \dots}) ERR_i$$
- Model GL-3:
(The GL-3 error term ERR_i is assumed to follow the Poisson distribution.)

Where: $COLL_i$ is the observed number of annual collisions in section i – usually this is a six-year average, although some test models were fit to collision counts for individual years;

L_i is the section length (miles);

ADT_i is the section annual average daily traffic;

$MEDTREE_i$ is either 0 or 1, indicating whether section i has median trees;

ε is the base of the natural logarithms (≈ 2.718);

X_{i1}, X_{i2} , etc. are other section characteristics from Table 1;

$\beta_0, \beta_1, \beta_2$, etc. are parameters associated with the various section characteristics, with estimates obtained from fitting the model to the data;

ERR_i is an error term accounting for effects not explicitly considered in the model.

For all models, the required variables, such as ADT, section length and the median tree indicator were entered first. Then trial models were created with different logical combinations of the other predictors. These were fit and any predictors judged non-significant were deleted one at a time until the best model for the given initial combination of variables was found.

For each model tested, the statistical significance of the $MEDTREE_i$ variable was examined to see if, in the presence of other variables, median trees appear significantly associated with the number of collisions (in GL-1 and GL-2) or with the severity ratio (in GL-3). Models GL-1 and GL-2 were applied to both total reported collisions and fatal and injury (F&I) collisions alone. Model GL-1 is believed to be conceptually superior to Model GL-2 for representing collision frequency since it treats section length and ADT in a more general way, while model GL-2 is essentially an extended accident rate model, in which collisions are assumed to vary linearly with section length and ADT, which past research has shown not generally to be true. In addition, goodness-of-fit statistics calculated for the fitted models generally indicated that GL-1 models produced superior fits.

In addition to modeling, the study performed a number of supplemental investigations to further explore the patterns of median tree collisions and to better understand the data used in the analysis. Breakdowns of collision attributes were compared for sections with and without median trees, including collision types, violation types, and associated environmental conditions such as weather and lighting. Approximately 100 of the most serious median-related collisions were singled out for further study, and original police reports were obtained and examined for additional insights. Locations, generally intersections, exhibiting clusters of collisions were examined with respect to visibility affecting turning conflicts as well as other possible explanations for the concentrations. In addition, the differences between posted and measured speeds were analyzed with regard to the existence of any biases from using different speed variables in modeling.

SELECTED FINDINGS

Examples of simple accident rates appear in Tables 3 through 5. These tables show rates (in accidents per million vehicle-miles) calculated for only the reported collisions that occurred within the median or median-shoulder areas. The rates in the left two columns correspond to all such reported collisions, while those in the right two columns exclude collisions at intersections. Intersection collisions are excluded because, unless there is a visibility issue, intersection collisions are probably unlikely to be affected by median trees. The “ \pm ” values in the tables are the bounds on error corresponding to the estimated 95% confidence intervals.

These simple accident rates present a mixed picture. As seen in Table 3, the average total accident rates, both with and without intersection collisions, are higher for sections with median trees than for sections without. The corresponding fatal and injury rates, while somewhat higher in the presence of trees, are so close that the 95% confidence intervals overlap. While this is a crude comparison, since simultaneous confidence intervals are not considered, it shows that the apparent differences in severity are small and, as a first approximation, statistically inconclusive.

In Table 4, stratification of rates by posted speed produced a surprising result. There is little if any evidence that lower posted speeds mitigate the association of median trees with higher total accidents, and few significant differences for F&I accidents are apparent, with the exception of the F&I rates for 40-45 mph sections when collisions at intersection are included. A similar counter-intuitive outcome appears in Table 5 with regard to variations in the setback distances to median trees. Greater setbacks appear to have little mitigating influence on the higher total accident rates for medians with trees.

Accident rate comparisons, while easily understood, are generally not well regarded within the accident modeling community due to invisible biases due to variables not considered in any given tabulation (such as effects of varying traffic volumes, roadway widths, etc. which are overlooked in the results shown above). Consequently, the principal conclusions of this study are based on multivariate modeling. It turns out that the findings of the multivariate modeling generally support and make more conclusive the preliminary findings presented above.

Tables 6 and 7 present two of the many multivariate generalized linear models that were developed. Most of the multivariate models give consistent results. Each includes different candidate variables from Table 1, or was fit to a different subset of collision data. The number of variables in each model is generally limited by the presence of correlations among some variables, and by the size of the data set. Both of the models shown in the tables were fit to all reported collisions (including both F&I and property damage), excluding collisions on the right side of the highway (away from the median) and excluding collisions located at intersections.

Table 6 shows a model of type GL-1, an exponential form where section length and average daily traffic (ADT) enter with estimated multipliers. Most model coefficients are significant at the 5% level with the exception of posted speed, which is significant at the 15% level (P-value = .143). The parameter representing the absence of median trees (MEDTREE = 0) is highly significant with a negative value (-0.3673). On face value, this parameter implies that, after controlling for the other included variables, sections without median trees have $e^{-0.3673} = 0.7$ as many no-right-side, non-intersection collisions as sections with median trees. This is about the same ratio shown in the data of Table 3. However, inferences such as this should be taken with considerable caution since no model perfectly replicates the real world, and the models developed here, in particular, are cross-sectional and cannot be expected to represent causality. The signs of the other coefficients for section length and ADT are both positive, as expected, and the signs for median curb height, median lane width, and commercial (as opposed to residential) land use are also positive, indicating a positive correlation with increased collisions. The coefficient values for posted speed are relative to a base of 45 mph. Therefore, the model implies that 35 mph sections have $e^{-0.1005} = 0.9$ times as many collisions as 45 mph sections, while 40 mph sections do best with $e^{-0.2853} = 0.75$ times as many collisions as 45 mph sections. As before, the expected mitigation effect of lower posted speeds does not appear. Data for 30 mph sections were excluded from this model because there are no 30 mph sections without median trees in the data set. Other models fit using measured 85th percentile speeds showed more of a mitigation effect of lower speeds, although not consistently.

In any modeling exercise, possible correlations among variables can produce distortions in the relationships observed. In this case, the correlation between posted speed and setback to trees corresponds to approximately 34% of the variation of one variable (say, speed) being explained by a linear relationship with the other (setback to trees). While this might distort the findings with regard to speed limits, the sample data indicate that this is a relatively weak association. Consequently, we believe that the counter-intuitive findings with regard to speed are valid.

Table 7 shows a model of type GL-3, an exponential form in which the dependent variable is the ratio of F&I to total reported collisions, a direct measure of severity. Most model coefficients are significant at the 10% level with the exception of ADT, which is significant at the 15% level (P-value = 0.131). The parameter representing the absence of median trees (MEDTREE = 0) has a negative value (-0.2613), indicating that the expected proportion of F&I collisions for sections without median trees is $e^{-0.2613} = 0.77$ times the proportion for sections with median trees. However, this estimate is only close to significant (P-value = .062, or about 94% confidence) so it is not possible to say with 95% confidence that collision severity for sections with trees is actually different from sections without. The impact of the posted speed variable on severity is again counter-intuitive, with both 35 mph and 40 mph sections showing higher severity than the base level of 45 mph (as before, 30 mph sections were not included).

Finally, the result with respect to median width defies easy interpretation. The narrowest medians, <10 feet (3 m.), are associated with highest proportion of F&I collisions while the most prevalent medium width medians, 10-16 foot (3-5 m.), are associated with the lowest proportion, both relative to the base level of medians wider than 16 feet (5 m.). Finally, narrow roadways having two directional lanes are seen to be associated with more severe collisions than wider roadways (three or four directional lanes), everything else being equal.

Numerous models, of which Table 6 and 7 are typical examples, were fit to the different data sets with mixed results. In general, multivariate models with strong statistical properties were found for total collision frequency, F&I collision frequency, and the F&I ratio in the case of data sets which exclude collisions on the right side of the roadway. Models with strong statistical properties were also found for the F&I ratio model type in the case of collisions involving only the median or median-shoulder. However, the collision frequency models for the left-side-only data set were generally poor with respect to statistical significance.

An example of a simple comparison made with regard to collision attributes appears in Table 8. It shows the breakdown of collision types in the case of fatal and injury collisions that involved the median or median-shoulder. Comparisons for these left-side-only collisions (LSO) with and without intersection collisions (LSONI) are shown. The values across each row of the table add to 1.0. The results show that median trees are associated with more hit-object (obviously hit-tree collisions). The increase in hit-object collisions is greater among these F&I collisions than in the corresponding table (not shown) for all collisions. Median trees are also associated with lower proportions of head-on and broadside collisions, and with a higher proportion of hit-pedestrian collisions, especially away from intersections. Other relationships seen in this part of the analysis (but not tabulated here) are that median trees are associated with higher proportions of collisions under wet and darkness conditions, and more single party and fewer 3+ party collisions occur in the presence of median trees.

The study also reviewed written collision reports for 96 selected fatal and injury collisions involving medians with trees. The review revealed that about 10% would very likely have been less serious had median trees not been present. However, a small number of the remaining collisions might actually have turned out worse had the trees not been there to prevent the runaway vehicles from entering oncoming traffic. Although this positive safety outcome from trees is a possibility, there is no way to know whether or not that actually occurred.

An additional follow-up investigation of a group of major collision clusters, which were all at intersections, revealed that the presence of median trees was most likely not a factor in causing the collision cluster. Rather, it appeared that the clusters were largely due to traffic conditions and access management problems.

CONCLUSIONS AND RECOMMENDATIONS

Median trees on urban and suburban conventional state highways were shown to be associated with increased numbers of total collisions and fatal and injury collisions, when collisions occurring on the right side of the roadway are excluded. The relative severity (proportion of F&I collisions) is also significantly higher in the presence of median trees. These findings hold whether or not collisions occurring at intersections are included in the data set. When collisions are further limited to those occurring in the median shoulder, the median, or beyond, a significant association was found between the presence of median trees and the proportion of F&I collisions in total collisions. However, only one close-to-significant model ($P=0.12$) was found linking median trees to the number of left-side-only collisions, which occurs only when collisions at intersections are included.

When the presence of median trees and certain other factors are controlled for, it was found that the number of collisions and collision severity usually, but not always, decrease with a reduction in actual (85thile) section speeds but, in most cases, the opposite occurs with posted speeds. In many models, when median trees and other factors are controlled for, both the number of collisions and collision severity increase with wider medians.

Although the data set assembled for this study includes nearly all of the urban conventional state highways with curbed medians in California that meet certain acceptability criteria, conclusions are based on a fairly small number of highway sections (20-29 data points for most models). This means that adding or dropping a single section might substantially influence the findings. In particular, one highway section in the data set with an unusually high proportion of F&I collisions (87%) and an unusually wide median (66 feet) appears to contribute substantially to the strength of the association found between median trees and the severity of left-side collisions. When this data point is temporarily removed, the presence of median trees no longer remains a statistically

significant variable; however it remains close to significant ($P=0.84$). This and other sensitivity tests support the overall conclusion that there does exist an association between median trees and the severity of left-side collisions, which although weak is still robust to minor changes in the data and model specification.

The presence of median trees was shown to be associated with some significant differences in collision characteristics. Most noteworthy is that there are increased proportions of hit-object collisions and decreased proportions of head-on and broadside collisions in the presence of median trees. There also exist associations between median trees and the proportions of hit-pedestrian collisions, especially when non-intersection collisions are considered. Not surprisingly, trees are shown to represent a greater proportion of the objects hit in F&I collisions where median trees are present. Also, in the presence of median trees, there are higher proportions of collisions under wet surface conditions and during darkness.

We believe this study provides conclusive statistical evidence under California conditions that the presence of median trees on urban conventional state highways is associated with increases in both the number and severity of collisions. We also believe such an important subject merits continuing investigation. It is recommended to broaden the analysis to other states. Also, since this study used cross-sectional statistical analysis (not before-after comparisons), it would be extremely useful to examine pertinent before-after data if they can be made available.

Further work related to collision mitigation in the presence of median trees is recommended. Research is needed into the design of aesthetically pleasing yet effective barriers and other treatments to prevent out-of-control vehicles from hitting large median trees. Note that developing acceptable designs for protection from trees in wide urban medians is just as important as finding solutions for trees in narrow medians. Community input should be an integral part of any such investigations.

Along the same lines, we recommend research into the “breakaway” and energy-absorption responses to vehicle impacts of different species and sizes of trees, shrubs and other plants suitable for urban highway medians.

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TABLE 1 Variables Used to Characterize Highway Sections

Median Trees or Not*	Section Length*	Average Daily Traffic in Each of Six Years*	Posted Speed*
Average Speed	Critical (85%ile) Speed*	Top and Bottom of Pace Speed Range	% Observations in 10 mph Pace Range
Number of Lanes*	Caltrans Rate Group ¹ *	Total Median Width*	Median Curb Height*
Median Shoulder Width	Setback – Curb to Median Trees*	Setback –Traveled Way to Median Trees	Median Tree Trunk Diameter*
Regularity of Median Tree Alignment	Right Curb Height	Right Shoulder Width	Right-Side Trees or Not
Setback – Curb to Right Side Trees	Right Side Utility Poles or Not	Right Side Parking or Not	Right Side Sidewalks or Not
Highway Curvature	Highway Grades	#1 Lane Width*	Right Lane Width
Nearby Land Use*	Cross Street Density ² *		

Notes: 1. Rate Group – A Caltrans designation used in reporting collision data, indicating highway type, urban setting, number of lanes, and design speed.

2. Cross-street density was used only with data sets including collisions at intersections.

TABLE 2 Range of Values of Selected Highway Section Characteristics

Section Characteristic	For 19 Sections With Median Trees			For 10 Sections Without Median Trees		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Section Length (miles)	0.9	6.3	2.1	0.9	3.8	1.8
Posted Speed (mph)	30	50	38.4	35	45	40.5
85%ile Speed (mph)	28.5	47.7	38.9	35.5	48.6	43.2
2001 Average Daily Traffic (veh./day)	19,500	59,500	36,774	33,095	81,400	50,459
Number of Directional Lanes	2	4	2.7	2	4	2.8
Median Width (feet)	11.0	66.0	22.0	4.5	28.0	14.2
Median Shoulder (feet)	0	2	0.7	0	2	0.5
Median Curb Height (inches)	1	12	6.1	3	8	6.0
Setback – Curb to Median Trees (feet)	3	12	6.7	-	-	-
Six-Year Exposure (MVM)	53	643	172	70	552	206

Note: 1 mi. = 1.61 km.; 1 in. = 25.4 mm.; 1 ft. = 0.305 m.

TABLE 3. Left-Side Accident Rates Stratified by the Presence/Absence of Median Trees

	Rates – With Intersections (Acc/MVM)		Rates – No Intersections (Acc/MVM)	
	Total	F&I	Total	F&I
W/ Trees	0.50±0.02	0.23±0.02	0.18±0.01	0.08±0.01
No Trees	0.34±0.03	0.19±0.02	0.12±0.01	0.06±0.01

Note: The ± values in the table represent approximate 95% confidence intervals.

TABLE 4. Left-Side Accident Rates Stratified by Posted Speed

	Posted Speed (mph)	Rates - With Intersections (Acc/MVM)		Rates – No Intersections (Acc/MVM)	
		Total	F&I	Total	F&I
W/ Trees	30-35	0.48±0.03	0.21±0.02	0.18±0.02	0.08±0.01
	40-45	0.54±0.04	0.27±0.03	0.19±0.02	0.09±0.02
	50+	0.40±0.09	0.18±0.06	0.14±0.05	0.07±0.04
No Trees	30-35	0.32±0.04	0.20±0.03	0.10±0.02	0.07±0.02
	40-45	0.36±0.03	0.19±0.02	0.13±0.02	0.06±0.01
	50+	no data	no data	no data	no data

Note: The ± values in the table represent approximate 95% confidence intervals.

TABLE 5. Left-Side Accident Rates Stratified by Setback from Curb to Median Trees

	Setback Distance (feet)	Rates - With Intersections (Acc/MVM)		Rates – No Intersections (Acc/MVM)	
		Total	F&I	Total	F&I
W/ Trees	≤ 4	0.45±0.15	0.24±0.11	0.17±0.09	0.09±0.07
	4-6	0.49±0.03	0.24±0.02	0.17±0.02	0.08±0.01
	6-8	0.54±0.04	0.22±0.03	0.21±0.03	0.09±0.02
	> 8	0.48±0.06	0.25±0.05	0.15±0.04	0.07±0.03
No Trees	--	0.34±0.03	0.19±0.02	0.12±0.01	0.06±0.01

Note: The ± values in the table represent approximate 95% confidence intervals.

TABLE 6. Multivariate Model GL-1 Estimated for All No-Right-Side Non-Intersection Collisions

Data Points (N): 22		Degrees of Freedom (DF): 13	
Variable	Estimate	Standard Error	P-Value
Intercept	-1.3999	1.2099	--
Section Length	0.3479	0.0364	<0.0001
Average ADT	0.3220	0.0651	<0.0001
Medtree = 0	-0.3673	0.1454	0.015
Posted Speed = 35	-0.1005	0.1840	0.143
Posted Speed = 40	-0.2853	0.1661	0.143
Median Curb Height	0.0619	0.0293	0.042
Median Lane Width	0.2078	0.0904	0.029
Land Use = Commercial	0.4201	0.1272	0.005

TABLE 7. Multivariate Severity Model GL-3 Estimated for No-Right-Side Non-Intersection Collisions

Data Points (N): 22		Degrees of Freedom (DF): 14	
Variable	Estimate	Standard Error	P-Value
Intercept	-1.2450	0.1912	--
Medtree = 0	-0.2613	0.1404	0.062
Posted Speed = 35	0.3586	0.1375	0.016
Posted Speed = 40	0.3718	0.1393	0.016
Median Width = 0-10	0.2074	0.1405	0.017
Median Width = 10-16	-0.2757	0.1161	0.017
Average ADT	0.0646	0.0427	0.131
# Lanes = 2	0.1833	0.0969	0.061

TABLE 8. Comparison of Reported Collision Types for Left-Side Fatal and Injury Collisions

Data	Median	Broadside	Rear End	Sideswipe	Hit Pedestrian	Hit Object	Head On	Other
LSO	Trees	0.56	0.03	0.05	0.05	0.12	0.07	0.12
	No Trees	0.66	0.03	0.03	0.03	0.06	0.11	0.08
LSONI	Trees	0.18	0.06	0.08	0.14	0.28	0.02	0.23
	No Trees	0.35	0.09	0.05	0.10	0.21	0.05	0.15

Note: LSO = left-side-only collisions, included all collisions involving median, median shoulder, or beyond.
 LSONI = left-side-only no-intersection collisions, same as LSO with intersection collisions eliminated.

Trees and Roadside Safety in U.S. Urban Settings

6,599 words (5,099 text, 2 tables, 4 figures)

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Abstract

Historically, transportation planning has focused on design objectives that achieve the highest levels of safety and capacity for roads at the lowest cost. This has frequently resulted in a roadside environment that ignores inherent characteristics such as community values and environmental amenities. The recent movement to incorporate context sensitive solutions into roadway and roadside designs has led to improved functionality of roads while maintaining high levels of safety. This study analyzes national traffic accident data to address questions relating to roadside attributes that are associated with accident incidence and severity, urban and rural spatial differences in accidents, the association between trees and roadside accident severity, and the implications for roadside planning, design, and management. The analysis involved the application of descriptive, comparative, and predictive modeling statistical methods to answer the research questions. The findings show that collisions with trees are more harmful than other types of accidents, accidents in rural areas are more harmful than accidents in urban areas, collisions with fixed objects are more frequent in rural areas than in urban areas, and that the statistical models predict accident outcomes with reasonable accuracy. From these findings, several conclusions may be drawn relating to context sensitive solutions. The clear zone philosophy, while arguably effective at improving safety, fails to incorporate community values and environmental amenities into design. A more comprehensive solution is proposed, including the implementation of collaborative design processes and the exploration of the idea of trees as technology to be incorporated into safe roadside designs.

INTRODUCTION

Historically, transportation planning has focused on design objectives that achieve the highest levels of safety and capacity for a road at the lowest cost. These goals have been accomplished by building wider lanes and shoulders, along with straighter and flatter alignments. Engineering economics, a historical mainstay of engineering schools, focuses on solving problems at the lowest cost with little emphasis on cultural or other impacts.

Citizens and communities began to perceive such design motives as being external decisions that had high local impact, but did not acknowledge diverse community values. Citizens have challenged construction of wide, 1950s-style highways through open space, neighborhoods and community centers. Recently, transportation planners have implemented practices of flexible highway design and context sensitive solutions (CSS) in an effort to balance issues of concrete and community.

CSS include participatory processes that ensure that transportation projects “fit” within the landscape, are sensitive to the interests of the local community, and do not unnecessarily impact important environmental, historic, and scenic values. Friendlier highway design must not compromise safety and mobility. Some of the greatest challenges facing CSS involve reconciling community input with the values of human life and property.

Trees within the driving environment have both community value and roadside safety consequences. Trees are imbued with historical, cultural and environmental value in communities, and are often a source of disagreement in CSS. More knowledge about the role of trees in accident incidence can better inform CSS programs throughout the U.S. Additional data are needed to better understand the causes and implications of the roadside urban forest for drivers who leave the road

A study was conducted, using national traffic accident data, to address the following questions:

1. What are the roadside attributes, with regard to roadside accidents, associated with incidence and severity?
2. Are such patterns of association different between urban and rural settings?
3. What are the associations between trees and roadside accident severity?
4. What are the implications for roadside urban forest planning, design, and management?

Literature Review

Two general approaches to improving roadside safety have emerged: deterrence and mitigation. Some safety planning emphasizes the importance of keeping cars on the roadway; other approaches emphasize reducing the severity of the consequences for not doing so. Largely absent from design policy, however, is the recognition of local community values, including urban forest issues. Environmental, aesthetic, and cultural considerations deserve greater attention in future roadside design research.

In 1981, the National Transportation Safety Board released a special study about safety issues specifically involving trees, and in 1988 AASHTO released a revised roadside design guide. The latter publication promoted the concept of designing “forgiving roadsides,” yet neglected to

discuss the role of trees in the new guidelines. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 brought changes. This act introduced environmental and aesthetic provisions as well as addressing safety in design, historically represented by organizations such as AASHTO and the Federal Highway Administration (FHWA) (1).

Updated in 2001, AASHTO's "Green Book" is the most current design guide and has been adopted by the FHWA as a national set of guidelines. Uniform application of these guidelines would provide national consistency for safety, but limitations persist with regard to environmental concerns (1). The 1997 FHWA Flexibility in Highway Design report provided ideas, options, and examples of ways to design more environmentally friendly highways without compromising safety and mobility. The guide stresses the importance of early public participation, identifying community interests, and fostering creative thinking as an essential component of achieving community highway design (2).

Solutions to Roadside Traffic Safety Problems

The AASHTO approach to roadside safety of removing, relocating, altering, and shielding hazards embodies a philosophy of mitigation. Clear zone policy emerged in a 1967 AASHTO report (the "Yellow Book") in response to a series of rapidly changing national standards of road safety design. Turner, et al. (3) reported that earlier there was no national consensus on what clear zones should be, that there was a diversity of clear zone development among states, and an inconsistent adoption of policies. The 1967 AASHTO report standardized clear zone definitions and guidelines.

More recently, Mak et al. (4) discussed clear zone requirements for suburban highways. Cost-benefit analysis was used to propose guidelines for clear zones that took into account conditions specific to each site. This direct cost approach is limited by the difficulties of quantifying public values for the more intangible properties of roadside features.

Community Values

Community values have been historically underrepresented in the discussion of transportation planning and safety. Roads are often treated as discrete land use entities, separate from the spaces surrounding them. In debate on the 1991 ISTEA and the National Highway Systems Act of 1995 Congress challenged the FHWA to consider environmental and cultural values, along with the traditional values of safety and mobility in the transportation decision-making process (1).

Passonneau (5) identifies two problems with the planning process: community concerns about highway proposals have been viewed as obstacles to be swept aside rather than as problems to be solved, and highway building has neglected the aesthetics of roads. Increased communication among state highway agencies, increased recognition and understanding of community and environmental interests, and a realization of opportunities for context sensitive design will be important future steps for designers (1).

Trees Benefits and Safety

Roadside trees are often considered expendable and are readily sacrificed in the face of safety concerns. Yet the urban forest provides extensive benefits and functions. Citizen based community values for trees are supported by empirical evidence. A program of studies at the

Center for Urban Forest Research confirms that trees in cities reduce storm water quantity and improve surface water quality, reduce urban heat island effects, reduce levels of pollution particulates in the air, and reduce building energy costs (6). Other investigators have found that trees affect urban economics by increasing desk worker productivity (7), residential property values (8), commercial rental rates (9), and shoppers' willingness to pay for goods in business districts (10). In the transportation context, drivers highly prefer views of trees in the roadside (11), and a view of nature while driving contributes to reduced physiological stress response in drivers (12).

Despite these extensive benefits, less research has been done on safety and trees in urban settings. Much urban policy is derived from rural precedents. An Australian study (13) is a rare example of urban policy based on research. The study intention was to address the increased number of accidents along busy roads and in areas with accident-prone geometry. The physical characteristics of different tree species were evaluated with respect to accident outcomes. A recent investigation in Palo Alto California (14) regarding accident rates associated with trees in urban highway medians found that California State policy overstated fatality and injury risk. The state-wide research resulted in a transportation agency variance that permits planting of larger trees within smaller setbacks adjacent to traffic lanes.

Despite these extensive benefits, little research has been done on safety and trees in urban settings. Most policy is derived from rural precedents. An Australian study (13) is a rare example of urban policy based on research. The study intention was to address the increased number of accidents along busy roads and in areas with accident-prone geometry. The physical characteristics of different tree species were evaluated with respect to accident outcomes. A recent investigation in Palo Alto California (14) regarding accident rates associated with trees in urban highway medians found that California State policy was not consistent with fatality and injury risk statistics. The state-wide research resulted in a transportation agency variance that permits planting of larger median trees within smaller setbacks adjacent to traffic lanes.

Methods

Using archival national transportation accident data, a progression of statistical analyses was carried out to better understand the relationships of trees and safety in urban transportation corridors. Analysis started with a reconnaissance of available data variables, and descriptive evaluations to understand the scope of the data set. Subsequent analyses involved greater complexity and predictive capacity, and revealed some limitations associated with the data set with respect to the research questions. Year 2002 data from the National Automotive Sampling System (NASS) General Estimates System (GES) database were used for this study. These data are collected by the National Center for Statistics and Analysis, a division of the NHTSA in order to identify traffic safety problems and conduct analysis of traffic related programs (15).

Analysis Variables

A subset of the 91 GES variables was used for analysis. Selection was based on which factors other researchers had found to be salient in prior studies, as well as original hypotheses on such relationships. The dataset included:

- Vehicle mass
- Alcohol consumption
- Driver gender

- Driver age
- Speed
- Restraint use
- Weather/light conditions
- Roadway geometry (gradient and curves)
- Traffic way flow
- Number of travel lanes

Additions to this list are:

- Urban/rural spatial component
- Nonlinear speed relationship
- Accident category
- Accident type
- Injury severity

Variable Transformation and Coding

Some variables needed for analysis were not present in the data set in a useful form. Certain variables were transformed to make them meaningful and useful. Other variables were absent and values had to be inferred from the values of other variables. Transformations were performed for the following variables:

- Vehicle mass
- Weather/light conditions
- Urban/rural spatial component
- Accident category

The transformations primarily involved creating dummy variables for the categorical values of the constructed variables. Vehicle mass was inferred from recorded vehicle body type to be light, medium, or heavy weight according to Environmental Protection Agency fuel economy classifications. Weather and light were transformed from specific meteorological conditions to adverse or non-adverse driving conditions. The location of the accident was defined as being either in an urban or a rural area. No explicit measurement existed for this spatial component in the data set, so index variables were created as proxies using these attributes:

Case Attributes	Urban Designation	Rural Designation
Population of accident area		>50,000 <50,000
Road width	4 lanes or fewer	any number of lanes
Speed limit	<45MPH	> 45 MPH
Road divided?	No & with 1 or 2 way traffic	No and two way traffic
Interstate highway condition	No	Yes or no, if met population

The accident category variable was collapsed into three dummy variables: collision with non-fixed object, collision with fixed object, and non-collision accident.

Comparative Analysis

Comparative analysis examined whether a difference exists between two groups across some measure. The hypotheses tested by comparative analysis relate to the research question “Are the patterns of association involving trees and roadside accident outcomes different between urban and rural areas?” Hypotheses were structured for two-tailed tests, using chi-squared analysis of categorical variables:

Is there a significant difference between:

- General accident category and injury severity?
- Specific accident type and injury severity?
- Accident location (urban vs. rural) and injury severity?

Examining accident location, is there a difference between urban/rural sites in terms of:

- Accident category?
- Incidence of striking fixed objects?
- Incidence of striking trees?

Predictive Analysis

Predictive analysis was used for the research question, “What are the implications for roadside urban forest planning, design, and management?” More specifically for the analysis methods, the question could be phrased “What factors influence the injury outcome of accidents, by how much, and which ones really matter?” Regression analysis was performed using binomial logit and ordinal probit models.

Model Choice

The binomial logit regression is the appropriate functional form for a dependent variable having two values. As the dummy dependent variable measured whether or not an accident resulted in an injury, the model coefficients predict the likelihood that an accident will result in an injury given a set of values for the explanatory variables.

The ordinal probit regression is appropriate when the dependent variable takes several discrete values in some inherent order. In the case of the second model, the dependent variable took five values along a continuum of injury severity ranging from no injury to fatality. An advantage is that the finer resolution of the dependent variable allows for a smoother gradient in the calculation of the coefficients. For example, variables whose explanatory powers were dampened in the “all or nothing” form of the binomial logit may emerge as better predictors in the underlying scale of the ordinal probit form.

The justification for including two separate but related models in the analysis is twofold. The ordinal probit model is a refinement of the binomial logit, and shows how a different measurement of the dependent variable reveals hypothesized relationships that were suggested at the level of comparative analysis. Secondly, a comparison of the two regressions shows that, with minor exception, the theoretical model is robust to changes in specification.

Variable Transformation

The following variables were constructed or transformed for use in the models. For the binomial logit model, the dummy dependent “Injury” variable was coded as a “1” = some injury was

sustained in the accident, and “0” = no injury was sustained. The choice of options for a dependent variable measuring some component of traffic safety was limited. One constraint of the GES data set, or any traffic safety data set, is that the only driving observations included are those that include an accident. There are no data recording non-accident occurrences. For the ordinal probit model, the dependent variable was coded as a scaled continuum of injury severity taking five discrete values. These were “no injury,” “possible injury,” “non-incapacitating injury,” “incapacitating injury,” and “fatality.” The structures of the explanatory variables are identical for both models (Table 1).

Results and Outcomes

The findings of the analysis are presented in three sections of increasing complexity: descriptive, comparative, and predictive analysis. The general conclusions drawn may be summarized as

1. Collisions with trees are more harmful than other types of accidents
2. Accidents in rural areas are more frequent and more harmful than accidents in urban areas
3. Collisions with fixed objects are more frequent in rural areas than in urban areas
4. The binomial logit and ordinal probit models predict injury outcomes reasonably accurately, but with variation in relationship strength.

Descriptive Analysis

The GES dataset defines three general accident categories. These include

- collisions with non-fixed objects
- non-collision accidents
- collisions with fixed objects

The most frequently occurring of these accident categories is that of collisions with non-fixed objects (85.2%), followed by collisions with fixed objects (10.1%) and non-collision accidents (4.7%). The data set enumerates more specific accident types (36 total). The four most common of these overall are car vs. car collisions (78.6%), rollovers (4%), collisions with poles or signs (2.1%) and collisions with trees (1.9%). Of all accidents involving only collisions with fixed objects, the top two objects struck are poles and signs (21%) and trees (19%), followed by guardrails (11%), ditches (11%), and traffic barriers (10%).

The average speed at which accidents occurred was 34 miles per hour. The speed, if not known at the time of the accident, was either estimated or reconstructed. Of all accidents, almost twice as many occurred in rural areas (63%) than urban areas (37%).

For all crashes, the majority (61%) of accidents resulted in no injury. Furthermore, 14% resulted in possible injury, 12% resulted in a non-incapacitating injury, 12% resulted in an incapacitating injury, and 1% resulted in fatality.

Trees as a Hazard

Based on the research questions, the rate, and characteristics, of collisions of cars and trees was examined. In the GES data set, there were 1,830 recorded instances of cars striking trees. Of all these collisions, 11.8% occurred on Federal interstate highways, the remainder occurred on non-interstate roads.

One notable difference in accident characteristics between tree collisions and all accidents is that of speed. The average speed at which drivers struck trees was 48 miles per hour. If not known, collision speeds were either estimated or reconstructed. This difference in mean accident speed (34 mph versus 48 mph) is significant ($t = 23.94$, $p < .01$), and the distributions are shown in Figure 1.

The proportion of accidents occurring in urban and rural areas was nearly identical for tree collisions as for all accidents. 39% of tree collisions occurred in urban areas while 61% occurred in rural areas. Collisions with trees were often harmful, as 61% of collisions with trees resulted in some sort of definite injury while in only 29% were the vehicle occupants unharmed.

The plurality of these accidents occurred on undivided roadways (48.8%), most commonly only with two lanes (40.3%), where the average speed limit was 52 miles per hour. This is consistent with the conclusion that a higher probability of collisions with trees exists in rural areas. Population attributes at crash sites are also consistent. Of all roadside accidents involving cars striking trees, 50.5% occurred in areas with populations less than 50,000 people. Exactly 40% occurred in areas with populations above 100,000.

Comparative Analysis

The research question, “Are there significant differences in roadside accident characteristics between urban and rural areas?” guided comparisons involving injury severity and accident location. Analysis addressed whether there are significant differences between these accident traits and injury severity:

- accident category (3 general categories)
- accident type (36 specific types)
- accident location (urban vs. rural)

Other tests examined accident location, and whether there a difference between urban/rural sites and:

- accident category?
- incidence of striking trees?
- incidence of striking fixed objects?

Accident Categories and Injury Severity

Certain accident categories do result in more serious injuries than others. Non-collision accidents are the most injurious, followed closely by collisions with fixed objects. Collisions with non-fixed objects are by far the most common accidents, but they are also the least injurious. Frequencies of injuries among the different accident categories are not independent ($\chi^2 = 7384$, $p < .01$).

Accident Type and Injury Severity

Also, some accident types result in more serious injuries than others. In a comparison of the four most frequent accident types, car vs. car is not only the most common but also the least injurious. Over 63% of all accidents of this type result in no injury, while only 11% result in serious injury or fatality. By contrast, rollovers are less frequent but result in injuries or fatalities at a much higher rate. In terms of the two fixed object collision types, striking a pole or post is generally

less injurious than striking a tree. While collisions with trees happen at the lowest frequency of these four accident types, the injury rates are higher than for all other accident types (Figure 3).

Accident Location and Injury Severity

Accidents in rural areas are likely to be more injurious relative to accidents in urban areas. There is a significant difference between urban and rural areas in terms of accident severity (chi square = 15, $p < .01$). All injury outcomes are more frequent in rural areas than urban areas. More accidents occur in rural areas as a percentage of all accidents, but the trends in accident severity appear similar for both rural and urban settings (Figure 4).

Accident Location and Tree Collision Incidence

There is no significant difference between urban and rural areas in relative collision incidence of cars striking trees (1.1% vs. 0.7%).

Accident Location and Accident Category

There is a significant difference between urban and rural areas in terms of collisions with fixed objects (chi square = 4.57, $p = .032$). Of all accidents in rural areas, 6.1% are collisions with fixed objects, whereas that type constitutes only 3.8% of urban accidents.

Predictive Modeling Results

The outcome variable for binomial logit model had no/yes values. Regressing a combination of explanatory factors against this measurement determined likely influences on the injury outcome and their relative magnitudes. The outcome variable for the ordinal probit model had five indicators of increasing injury severity. The model is mathematically similar to the logit function, but provides greater precision in estimating the coefficients in terms of the scaled dependent variable.

Model Interpretations

Due to the non-linear mathematical nature of the binomial logit model, it is difficult to evaluate its predictive power using the same measurements as for linear models. The reported Nagelkerke pseudo- R^2 value for this model is .117 and the goodness of fit chi-squared statistic is significant at the .01 level. The reported R^2_p is .642, meaning that this model correctly predicts the injury outcome about 64% of the time. The model correctly predicted that no injury would result 84% of the time, while predicting that some injury would result 37% of the time. This discrepancy reflects the fact that injuries occur in only a small percentage of all accidents and thus the distribution of accident outcomes is not normal.

The ordinal probit model results are similar to those of the binomial logit. The reported Nagelkerke pseudo- R^2 is .107 and the goodness of fit chi-squared statistic is significant at the .01 level. A comparison of the two models shows that their estimates are generally consistent across functional forms. Table 2 compares the coefficients and associated p-values of all explanatory variables across both models. Since interpretations of the coefficients are relative, they have all been normalized to the speed coefficient so they may be compared on the same scale. For both models, the explanatory variables speed, vehicle weight, driver gender, road geometry, and accident category were significant at the 95% level or higher. For the binomial logit model, the non-linear speed variable was also significant, while for the ordinal probit model the urban/rural spatial variable was significant.

The structure of the dependent variable is a drawback of the logit model. The coding of the variable is binary; thus there is no distinction between degrees of injury severity, so a broken bone is treated the same as a fatality. The variable was structured in this way to explore whether or not there were relationships between the explanatory factors and any injury outcomes, as opposed to specific injury outcomes.

To a certain extent the vagaries of the logit model are improved upon by the ordinal probit model. This model provides the finest resolution permitted by the data set. A small number of coefficients differ between the two models but the results across both are generally consistent. Furthermore, differences that were significant in the comparative analysis, specifically the urban/rural spatial component, are also shown to be significant predictors of accident outcome in the ordinal probit model. Taken together, the two models show that the explanatory factors are robust to changes in specification.

Discussion

The research outcomes discussion will incorporate the broader ecology of accidents, roadside environments, and trees. Findings of this study have planning and policy implications for both deterrence and mitigation strategies, and future research efforts on roadside safety.

Findings Summary

Comparative analysis addressed research questions about patterns of association between urban and rural settings. Accident frequency in general is higher and injury outcome is more severe in rural areas than in urban areas. With regard to trees, the majority of tree collisions occurred on undivided, two-lane roads for which the average speed limit was 52 miles per hour. Collisions with trees are more injurious than all accidents in general. While there is no significant difference in tree collision rates between urban and rural areas, there is a significant difference between urban and rural areas for collisions with all fixed objects. The predictive models describe the associations between trees and roadside accident severity. Both models show that trees, as fixed objects, increase the likelihood of injury in accidents. Nonetheless, trees are involved in a small percentage of all accidents and collisions.

The predictive models also demonstrate that the significant explanatory factors external to the driver influencing injury outcome are road geometry, urban/rural setting, accident category, and vehicle weight. From the solution approach of deterrence, these findings would suggest that, in order to reduce the likelihood of injury in accidents, the installation of safety devices such as rumble strips, warning signs, and guardrails should be increased on rural roads. These physical deterrents would improve safety by helping to reduce the likelihood of cars leaving the roadway. Deterring consumers from buying certain types of cars is an impractical solution, but the current propensity for heavier vehicles in the United States means that drivers of those vehicles will be somewhat safer in certain types of accidents while injury risk increases for drivers of lighter vehicles.

Traditional Safety Design

From the mitigation perspective, the findings suggest that roadside objects pose a major hazard and should be removed, relocated, or shielded. The universal adoption of clear zone policies would probably reduce the likelihood of accidents resulting in injuries. Taken at face value, this would imply large-scale removal of trees from the roadside.

One superficial implication of the findings is that they provide further support for planners to pursue the mitigation approach to roadside traffic safety. This interpretation, however, is simplistic. Mitigation, while a popular design philosophy in safety engineering, is not necessarily the most comprehensive approach to reducing roadside traffic accidents. Mitigation may also be more expensive than deterrence. The attitude that improved safety should be achieved primarily through physical alteration of the landscape is specious, and limits the potential of incorporating diverse, effective, and sustainable ameliorations into the roadside environment.

Use of clear zone and forgiving roadside mitigations provide ostensibly efficient solutions. They reflect an engineering perspective focused on mechanical attributes of fixtures and assumptions about driver fallibility- people will continue to drive off the road, so the fewer and friendlier objects they can hit, the better. The majority of the research exploring roadside safety improvements has dealt with either landscape transformations or technological developments to reduce hazards to drivers. Very little attention has been paid to the role of trees.

Trees as Technology Research

Other than acknowledging their dangers as fixed objects, transportation planners have done little to develop a deeper understanding of how trees can be integrated into a safe roadside environment. Trees are regarded as fixed objects that cannot be redesigned like signposts, and since they possess no inherent technological benefit, it is often thought best to simply remove them. While outright removal may lead to a reduction in injurious roadside accidents, it does so without taking into account the benefits trees provide or their value to communities. The current engineering solutions are constrained by a narrow understanding of trees' potential contributions to the safety of the roadside environment and their role in its design.

The issue should not be simply framed as one of safety versus aesthetics and environment, but rather one of how trees can be effectively incorporated into a safe roadside design that integrates engineering, community values, and environmental amenities. Extensive research effort has been directed to developing roadside object technologies, such as breakaway poles and energy absorbing guard rails. Meanwhile, trees have been largely neglected as an engineering problem. Trees are another roadside technology. Research about the physical properties of various trees in collisions would enable roadside design that integrates plant life as a safety feature.

This concept has been applied in a limited way in Australian urban roadsides (13). The Traffic Authority of New South Wales addressed an increasing number of accidents along busy roads and in areas with accident-prone geometry by developing a tree planting policy. Minimum distances from the roadway were specified for certain types of trees, and the Authority differentiated between the physical characteristics of different tree species, namely how their physical properties related to accident outcomes. Emphasis was placed on improving driver visibility and selecting frangible (breakable) trees for stretches of road that were more prone to run-off-road accidents.

Communities and Planning

Mitigation approaches must also acknowledge community values. Policy makers may appreciate the need for community values to be reflected in roadway design, but the difficulty lies in

implementation. Community values have not been systematically incorporated into the transportation engineering process or resulted in physical transformations of the roadside on a broad scale. How should planners go about taking ideas from a community and manifest them in the roadside environment? This problem begins to move away from engineering and into the realm of public affairs and social science.

A collaborative design process that brings together engineers, natural scientists, local officials, and community leaders would be a good first step in acknowledging that community and environmental values can be integrated with traffic safety. As roadway designers become increasingly aware of the diversity of interests in planning that go beyond transportation efficiency, the role of community stakeholders in the design process will gain importance. Governments will continue to build and upgrade roads, and this will invariably create conflict within communities. The contribution of public opinion to the planning process may lead to broader acceptance of public works than a unilateral declaration of the design made by a closed group of designers and officials. To this end, designers should address the need for creating roadways and roadside environments that are influenced by the desires of the communities in which they are built.

The design features of the parkway, as described by Passonneau (5), appear to effectively address many issues of traffic safety, community values, environmental benefits, and aesthetics. Parkways are a successful integration of the pavement with surroundings, as well as having safety records comparable to expressways. If drivers are introduced to a roadway setting which is scenic and has perceptible environmental amenities, which has lower traffic speeds but handles traffic volumes efficiently, and in which they feel like they had some input in developing, they are more likely to view the roadway as a part of their community and less as a mundane transportation corridor.

Additional research is needed to effectively address the interconnected issues of traffic safety, community values, environmental benefits, and aesthetics. Urban trees and forests are not only aesthetic roadside elements, but have been scientifically confirmed to provide extensive human health and welfare benefits. There are several research needs. First, greater clarity is needed in accident data collection and interpretation, so that the distinct accident circumstances of urban, suburban and rural areas can be distinguished. A limited amount of research has been done on urban trees and transportation impacts; most studies have been done locally or regionally and should be expanded in scope to address national scale issues. Additional research is needed to better understand the “technology of trees” and associated built structures. Finally, empirical investigations generally yield insights that suggest refinements if follow-on studies are undertaken (14); a commitment to tree-based research is needed in order to generate a “critical mass” of knowledge that can be translated into policy and guidelines. Better understanding of trees and urban roads will contribute to transportation systems that are more safe, handle traffic volumes efficiently and are perceived as community assets.

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TABLE 1 Descriptions of Variable Structures as Used in the Models

Independent Variable	Variable Structure
Vehicle Weight	3 dummy variables (heavy, midweight, lightweight), lightweight vehicles were omitted from the model as the reference case
Alcohol	Dummy variable, 1=alcohol involved, 0=not involved
Atmospheric Conditions	Dummy variable, 1=inclement weather, 0=moderate weather
Driver Gender	Dummy variable, 1=male, 0=female
Driver Age	Continuous variable, actual driver age in years
Speed	Continuous variable, actual or estimated speed in miles per hour
Speed Squared	Continuous variable, quadratic speed term
Roadway Geometry	Dummy variable, 1=curve in roadway, 0=straight roadway
Restraint Use	Dummy variable, 1=restraint used, 0=no restraint used
Accident Category	3 dummy variables (non-collision, fixed object, non-fixed object), non-fixed object category omitted from model as reference case

TABLE 2 Predictive Model Results, Coefficients Normalized to Speed

Variable	Binomial model Coefficient (P-value)	Ordinal model Coefficient (P-value)
Speed	1 (<.01)	1 (<.01)
Speed squared	.000 (<.01)	$3.24 * 10^{-4}$ (.928)
Heavyweight	-39.10 (<.01)	-54.87 (<.01)
Midweight	-8.62 (<.01)	-11.37 (.015)
Male	-6.52 (<.01)	-7.38 (.029)
Curve	-7.29 (.033)	-11.75 (.018)
Non-collision	69.52 (<.01)	100.38 (<.01)
Hit fixed object	36.10 (<.01)	53.25 (<.01)
Urban locale	-3.95 (.09)	-9.13 (<.01)
Alcohol	-1.71 (.665)	-0.75 (.897)
Adverse conditions	-4.05 (.219)	-7.35 (.123)
Age	-.048 (.653)	-0.125 (.322)
Hill	0.95 (.736)	2.0 (.630)
Restraint use	4.33 (.188)	2.88 (.554)

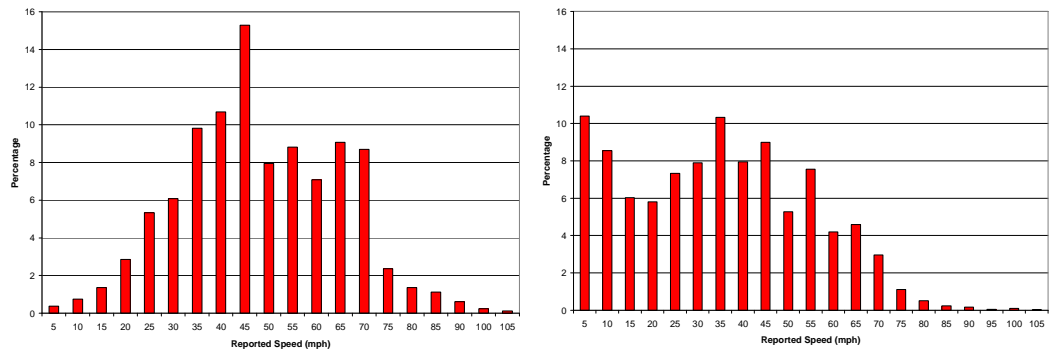


FIGURE 1 Comparison of accident speeds between tree collisions and all accidents (%).

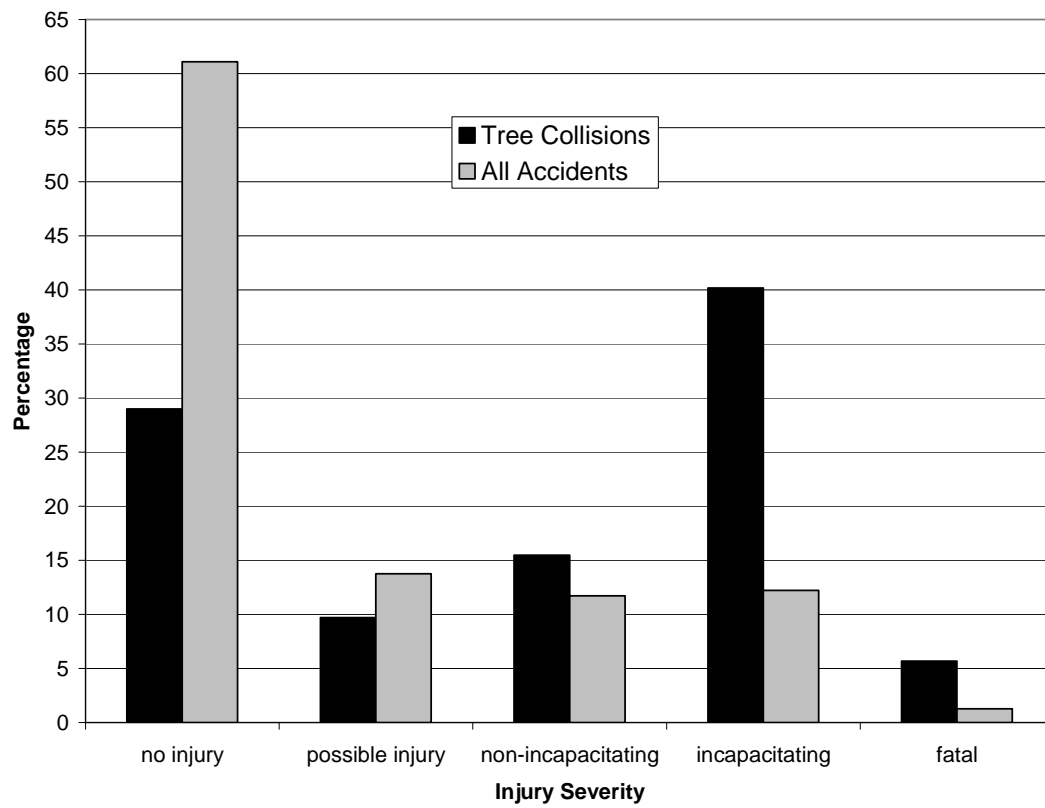


FIGURE 2 Relative frequency of injury severity for tree collisions and all accidents (%).

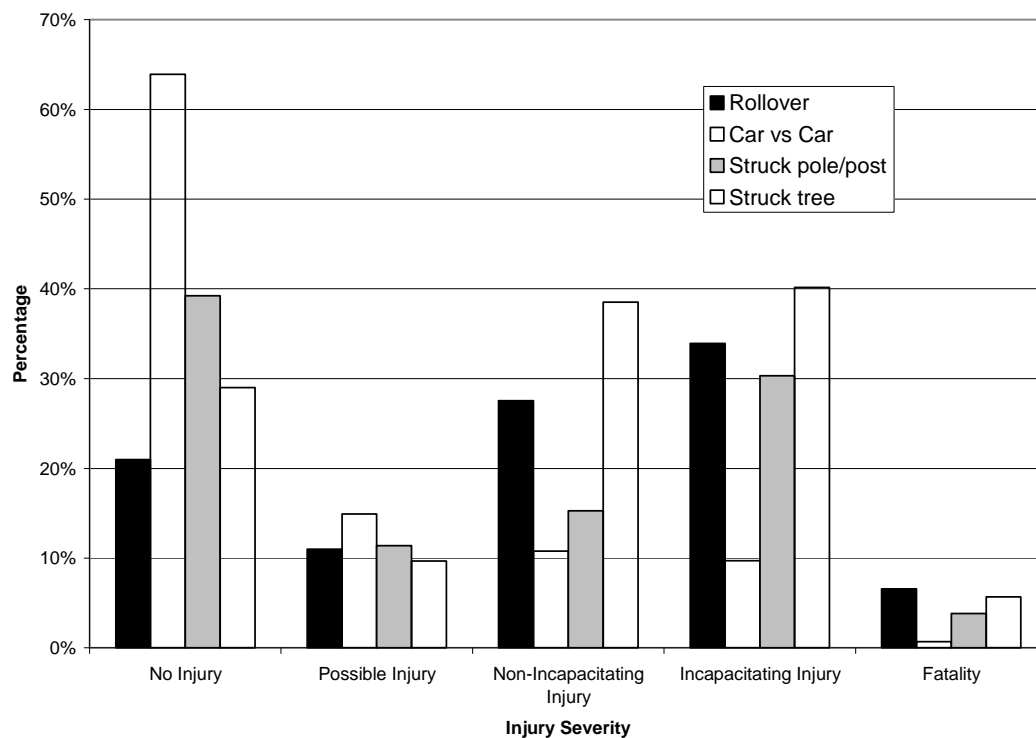


FIGURE 3 Relative frequency of injury severity by accident type.

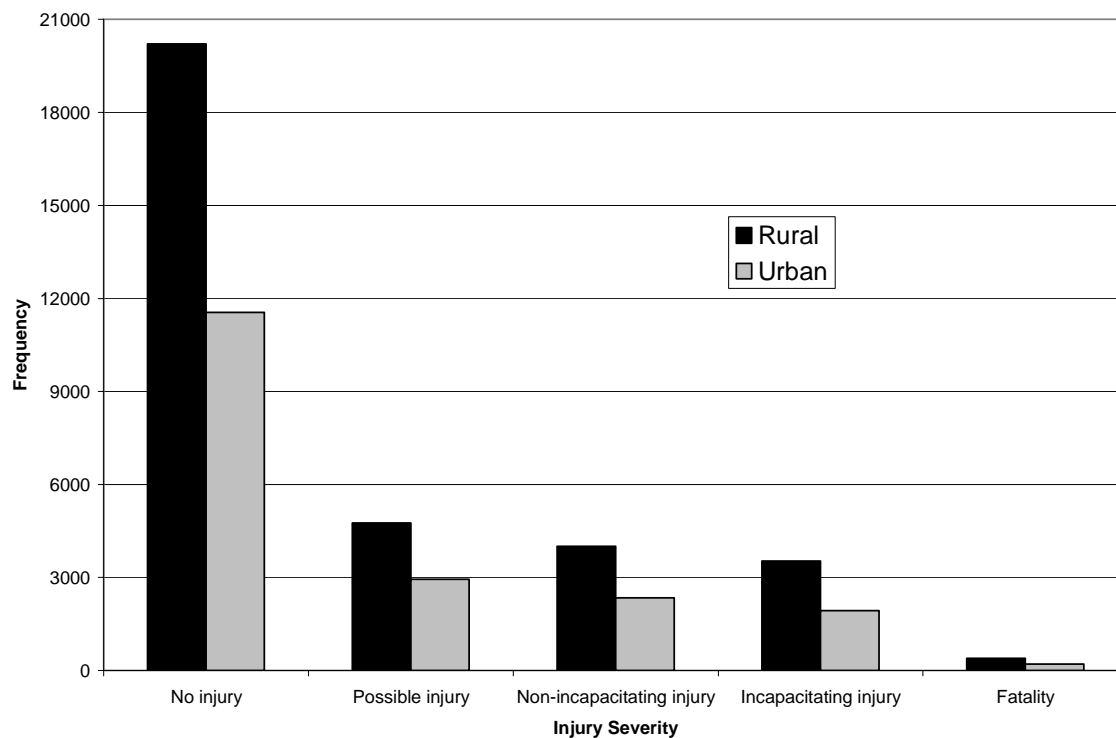


FIGURE 4 Distribution of injury severity by urban and rural areas.